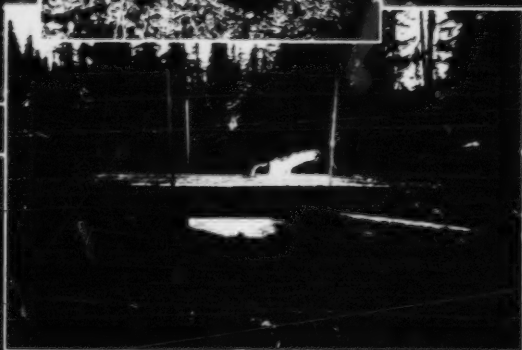
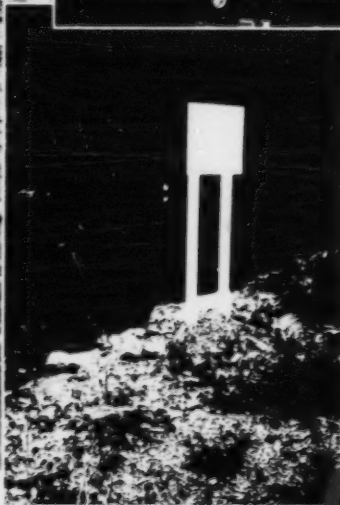
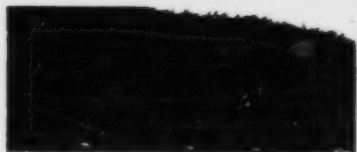


**HYDROGEOLOGY AND GROUNDWATER RESOURCES MANAGEMENT
BELL ISLAND, CONCEPTION BAY
NEWFOUNDLAND**

**WATER RESOURCES
REPORT 3-1
GROUNDWATER SERIES**



**GOVERNMENT OF NEWFOUNDLAND
AND LABRADOR**

**DEPARTMENT OF ENVIRONMENT AND LANDS
WATER RESOURCES DIVISION**

HYDROGEOLOGY AND GROUNDWATER RESOURCES MANAGEMENT
BELL ISLAND, CONCEPTION BAY
NEWFOUNDLAND

Prepared for:

Newfoundland and Labrador
Department of Environment

February 1989

Nolan, Davis & Associates Limited
St. John's, Newfoundland



TABLE OF CONTENTS

	Page No.
SECTION A - Project Rationale and Study Strategy	1
A-1.0 PROJECT RATIONALE	1
A-2.0 STUDY STRATEGY	2
A-3.0 PHILOSOPHY OF APPROACH	3
A-4.0 REPORT OUTLINE	4
A-5.0 ACKNOWLEDGEMENTS	4
SECTION B - Existing Fresh Water Resources	5
B-1.0 INTRODUCTION	5
B-2.0 SITE LOCATION/ECOZONE	5
B-3.0 GEOLOGY	5
B-3.1 Bedrock Geology	5
B-3.1.1 Stratigraphy	5
B-3.1.2 Structure	12
B-3.2 Surficial Geology	14
B-3.2.1 Ground Moraine	14
B-3.2.2 Outwash Deposits	16
B-3.2.3 Organic Terrain	16
B-3.2.4 Man-Made Deposits	16
B-3.3 Pedology	16
B-3.4 Physiography	19
B-3.5 Long Term Trends	19
B-4.0 CLIMATE	20
B-4.1 Introduction	20
B-4.2 Precipitation	20
B-4.3 Air Temperature	23
B-4.4 Evaporation	24
B-4.5 Evapotranspiration	24
B-4.6 Wind	26
B-4.7 Long Term Trends	26

TABLE OF CONTENTS (cont'd)

B-5.0	HYDROLOGIC CYCLE	29
B-5.1	Definition	29
B-5.2	Surface Water Hydrology	29
B-5.2.1	Introduction	29
B-5.2.2	Drainage Basin Morphology	32
B-5.2.3	Channel Morphology	35
B-5.2.4	Water Discharge	35
B-5.2.5	Limnology	39
B-5.3	Groundwater Hydrology	41
B-5.3.1	Bell Island Hydrostratigraphic Unit	41
B-5.3.2	Redmond Hydrostratigraphic Unit	42
B-5.3.3	Wabana Hydrostratigraphic Unit	43
B-5.3.4	Till Hydrostratigraphic Unit	43
B-5.3.5	Soil Hydrostratigraphic Unit	44
B-5.3.6	Organic Hydrostratigraphic Unit	44
B-5.3.7	Fill Hydrostratigraphic Unit	44
B-5.4	Conceptual Flow Model	44
B-5.4.1	Generation of Flow	45
B-5.4.1.1	Surface Water	45
B-5.4.1.2	Groundwater	47
B-5.4.2	Routing of Flow	52
B-5.5	Resource Calculations	52
B-5.5.1	Replenishable Resource	53
B-5.5.2	Non-Replenishable Resource	53
B-6.0	GEOCHEMICAL CYCLE	54
B-6.1	Definition	54
B-6.2	Geochemical Landscape	56
B-6.3	Element Mobility	58
B-6.3.1	Precipitation Chemistry	59
B-6.3.2	Surface Water Chemistry	62
B-6.3.3	Groundwater Chemistry	62
SECTION C - Human Cycle		68
C-1.0	INTRODUCTION	68
C-2.0	HUMAN CYCLE	68
C-3.0	MINING CYCLE	70
C-3.1	Extraction	71
C-3.2	Beneficiation	72
C-3.3	Transportation	72
C-3.4	Markets	74

TABLE OF CONTENTS (cont'd)

C-4.0	HARVESTING CYCLE	74
C-4.1	Agriculture	74
C-4.2	Forestry	75
C-5.0	RESTRUCTURING CYCLE	76
C-5.1	Population	76
C-5.2	Land Use Conversion	78
C-5.3	Transportation	80
C-5.4	Energy Sector	81
C-5.5	Water Supply Systems	81
C-5.5.1	Utilities	82
C-5.5.1.1	Incorporated District - Wabana	82
C-5.5.1.2	Unincorporated Area - Lance Cove	84
C-5.5.2	Demand	84
C-6.0	WASTE CYCLE	85
C-6.1	Municipal Solid Waste Stream	87
C-6.2	Municipal Liquid Waste Stream	87
C-6.3	Mining Waste Stream	89
C-7.0	FUTURE DEVELOPMENT AND WATER DEMANDS	90
SECTION D - Water Resources Management		93
D-1.0	INTRODUCTION	93
D-2.0	FRESH WATER RESOURCES	95
D-2.1	Resource Potential for Man	95
D-2.1.1	Water Supply	95
D-2.1.2	Energy Resource	97
D-2.1.3	Attenuation of Contaminants	99
D-2.2	Present Utilization by Man	99
D-2.2.1	Water Supply	99
D-2.2.2	Contaminant Attenuation	100
D-2.3	Water Resources Imbalances	101
D-2.4	Water Resource Conflicts	102

TABLE OF CONTENTS (cont'd)

D-3.0	WATER RESOURCES MANAGEMENT	103
D-3.1	Philosophy of Approach	103
D-3.2	Management Strategy - Organization of a Management Authority	103
D-3.3	Management Schemes	105
D-3.3.1	Development of Continuous Working Models	106
D-3.3.2	Monitoring/Research Programs	110
	D-3.3.2.1 The Hydrologic Cycle	110
D-3.3.3	Permit System	114
D-3.3.4	Setting up a Data Base	114
D-3.3.5	Environmental Impact Assessment	116
D-3.3.6	Definition of Safe Yield	116
D-3.3.7	Creation of Water and Waste Management Districts	120
D-3.3.8	Development of Groundwater Protection Zones	121
D-3.3.9	Water Pricing	126

LIST OF REFERENCES

APPENDIX A	Historical Streamflow Summary of Water Discharge at Rocky River (Colinet) and Waterford River (Kilbride)
APPENDIX B	Precipitation Chemistry Data
APPENDIX C	Well Inventory File
APPENDIX D	Municipal Wells - Fact Sheet

TABLE OF CONTENTS (cont'd)

Page No.

LIST OF FIGURES

B-1	Location Map	6
B-2	Regional Stratigraphic Setting - Bell Island	7
B-3	Cross Section of Faults in Underground Workings	13
B-4	Surficial Geology of Bell Island	15
B-5	Soils of Bell Island	17
B-6	Location of Pertinant Climatic Stations	21
B-7	Running Decadal Means of Annual Precipitation at St. John's Airport	28
B-8	Canonical Representation of Hydrological Cycle	30
B-9	Surface Watersheds - Bell Island	31
B-10	Relationship of Drainage Area to Mainstream Length	34
B-11	Drainage Density versus Texture Ratio	34
B-12	Longitudinal Channel Gradient	36
B-13	Location of Pertinent Hydrometric Stations	38
B-14	Water Balance Diagram - Bell Island	48
B-15	Diagramatic Representations of the Geochemical Cycle	55
C-1	Civilization Engine	69
C-2	Extent of Underground Mine Workings	73
D-1	Suggested Heirarchy of Continuous Working Models For Bell Island	108

TABLE OF CONTENTS (cont'd)

Page No.

LIST OF TABLES

B-1	Depositional Environments of the Bell Island and Wabana Groups	9
B-2	Climatic Summary - 1951-1980 Normals for "Seal Cove"	22
B-3	Mean Monthly Evaporation and Evapotranspiration Rates For Seal Cove	25
B-4	Wind Speed and Direction for St. John's A Station	27
B-5	Drainage Basin Morphology - Bell Island	33
B-6	Predicted Flows for Major Watersheds on Bell Island	40
B-7	Whole Rock Analyses of Ore and Non-Ore Zones	57
B-8	Precipitation Chemistry Summary - Bay D'Espoir 1984, 1985, and 1986	61
B-9	Surface Water Chemistry	63
B-10	Groundwater Chemistry	64
C-1	Agricultural Activities, Bell Island 1955-1966	75
C-2	Population of Bell Island 1845-1987	77
C-3	Land Use Bell Island 1975	79
C-4	Estimated Daily Water Demand Bell Island 1988	86
C-5	Future Predictions of Bell Island Water Demand	92
D-1	Summary of Pump Test Analyses	98

SECTION A PROJECT RATIONALE AND STUDY STRATEGY

A-1.0 PROJECT RATIONALE

The Newfoundland Department of Environment is vested with the exclusive responsibility for the conservation, development, control, improvement and proper utilization of the water resources of the province.

Due to increasing pressure on the resource in certain areas from recent population increases and economic development, the department felt it was imperative that groundwater resource management strategies be developed on a local scale to ensure security and quality of groundwater supplies on an efficient, cost effective basis. Bell Island was selected for the first study of this nature.

The present development on the island stems in large measure from the Wabana Iron Ore Mines which were operated from 1895 to 1966. During peak mine operation the island supported a population of 13,000; today it is about 4,500. It presently serves as a satellite community to St. John's.

The island's groundwater resources provide a major part of not only residential need but also the commercial requirements i.e. hospital, schools, recreational and government buildings. In recent years problems have been experienced in trying to obtain groundwater supplies for major users not only in terms of yield but acceptable quality. In addition, suggestions have been made to use the mine workings as an oil storage and trans-shipment facility or as a pumped storage hydroelectric power generating station. Such proposals, to be viable, would both necessitate suitable water supplies and place an even greater demand on the resource.

In response to these existing and potential pressures on the groundwater resources of Bell Island, the Newfoundland Department of Environment, commissioned Nolan, Davis & Associates (NDAL) to undertake a hydrogeological and groundwater resources investigation of the island.

A-2.0 STUDY STRATEGY

The overall objective of this program was to assist government in the protection and management of the groundwater resources of Bell Island. Specifically this was to include the following items:

- 1) Define the ground/surface water flow field on the island in terms of both its physical/chemical characteristics.
- 2) Identify the safe yields capable of being withdrawn at various points within the field.
- 3) Evaluate existing water supply systems in terms of water quantity/quality and assess future needs for the next 25 years.
- 4) Integrate supply and demand data and identify where supply can meet expected demands and where supply/demand imbalances are presently occurring or may occur.
- 5) Identify present and future resource conflicts and recommend measures to resolve the problem.
- 6) Identify areas with existing or emerging problems of deteriorating water quality due to natural and man-made land-use activity.
- 7) Define site specific recommendations relating to the planning and management of water resources in the study area.

These investigations were defined within the following boundary conditions:

1) **Administrative Boundaries**

The principal constraint concerned the level of detail and duration of the study. Specifically, only existing data was initially to be utilized and interpreted within six months. Given the limited data available, the report was limited to order-of-magnitude descriptions and predictions.

2) **Project Boundaries**

The spatial constraints defined the entire island as the study area.

3) **Technical Boundaries**

The report was to be directed specifically towards the physical and chemical characteristics of fresh water resources on the island. The saline water resource surrounding the island and the utilization of water by aquatic or other terrestrial life was excluded.

This report details the results of these investigations.

A-3.0 PHILOSOPHY OF APPROACH

Accomplishing such an undertaking, particularly when dealing with complex processes on a scale of individual watersheds necessitated assessing the problem in terms of integrated, process-response systems or cycles. This concept is best summarized by Chorley and Kennedy (1971):

"The real world is immensely complex. man reacts to this by trying, first to isolate parts of reality-either in fact or in theory-and, second, to monitor how the parts operate under simplified conditions. However, the real world is continuous and can be viewed as comprising sets of interlinked systems or cycles at various scales and varying complexity which are nested into each other to form a systems hierarchy. Therefore, isolated structures are subjective and artificial portions of reality"

The identification of meaningful sections of the "real world" was completed by deciding to isolate the two major "systems" or "cycles" which define the quantity and quality of freshwater flow within a watershed, specifically:

- 1) the Hydrological Cycle and
- 2) the Geochemical Cycle

The third and fourth critical cycles are the Debris and Biological Cycle, which are outside the terms of reference. However, where a process-response action is present such that feedback from the biological cycle alters the above cycles (i.e. vegetation effect through evapotranspiration), that action is discussed in the relevant section.

It was then a logical progression to define man-made activities in the form of the "Human Cycle", and determine how it interlinked with the two natural cycles, under consideration.

This approach allowed for a clearer understanding of not only what and where the short and long term impacts of man-made activities will be in both space and time; but to allow for the prediction of whether such a change is critical enough to delay a project, require the installation of mitigation techniques (i.e. risk management), or install specific protection guidelines in order to manage the resource.

A-4.0 REPORT OUTLINE

The results of the investigation are presented in four major sections within this report:

Section A - Project Rationale and Study Strategy

This section defines the rationale for undertaking the investigation. Further, it develops the strategy upon which the investigation was based and the boundary conditions which defined it.

Section B - Existing Fresh Water Resources

This section presents a comprehensive description of the physical/chemical aspects of the fresh water resources on the island.

Section C - The Human Cycle

The Human Cycle is defined in this chapter and its various components discussed with specific reference to the demands and other stresses which they place on the water resources of the island.

Section D - Management

The final section summarizes present water resources on the island and the stresses placed upon them. It further defines various strategies for managing the resources to mitigate the impacts and manage the Human Cycle.

A-5.0 ACKNOWLEDGEMENTS

NDAL would like to acknowledge the aid and direction provided by Mr. J. Robinson of Newfoundland Environment.

Numerous individuals from a variety of provincial and municipal agencies as well as local people living on the island, gave freely of their time and energy to aid us in gathering the necessary data for the report. To those, we would sincerely extend our thanks. Specifically, we would like to recognize:

Ms. M. Stoyles - Town Clerk - Wabana
Mr. M. Hammond - Water Well Drilling Contractor
Mr. P. Kent - Town Manager - Wabana
Mr. G. Hawko - former town manager - Wabana
Ms. M. Cahill - Public Health Inspector
Mr. R. Noseworthy - L.I.D. Chairman Lance Cove

SECTION B EXISTING FRESH WATER RESOURCES

B-1.0 INTRODUCTION

This chapter presents as comprehensive a description as possible of the physical/chemical aspects of the fresh water resources on Bell Island, given the extent of existing data.

The parameters are discussed in order of increasing dependency i.e. the relatively independent parameters of geology/pedology, climate, and vegetation followed by the hydrological cycle, and geochemical cycle.

B-2.0 SITE LOCATION & ECOZONE

Bell Island is located in Conception Bay, Newfoundland (Figure B-1). Specifically, it is situated between approximately 52° 54' to 53° 01' west longitude and 47° 35' to 47° 39' north latitude. The island is roughly rectangular in shape, being some 10.5 km long and 3.6 km wide; encompassing approximately 31 km².

This location places it within the Boreal Shield Ecozone of Canada (Statistics Canada, 1986).

B-3.0 GEOLOGY

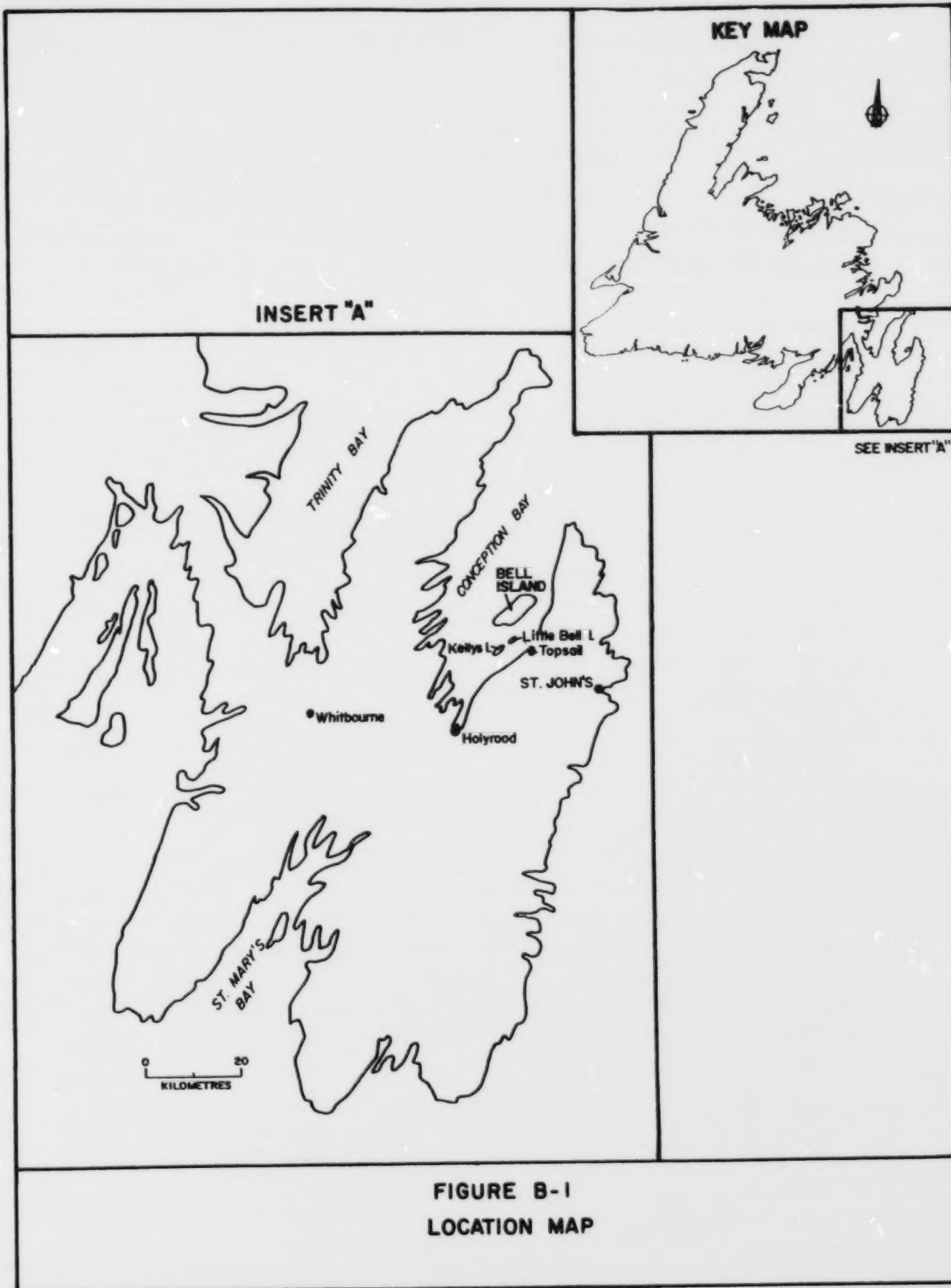
B-3.1 Bedrock Geology

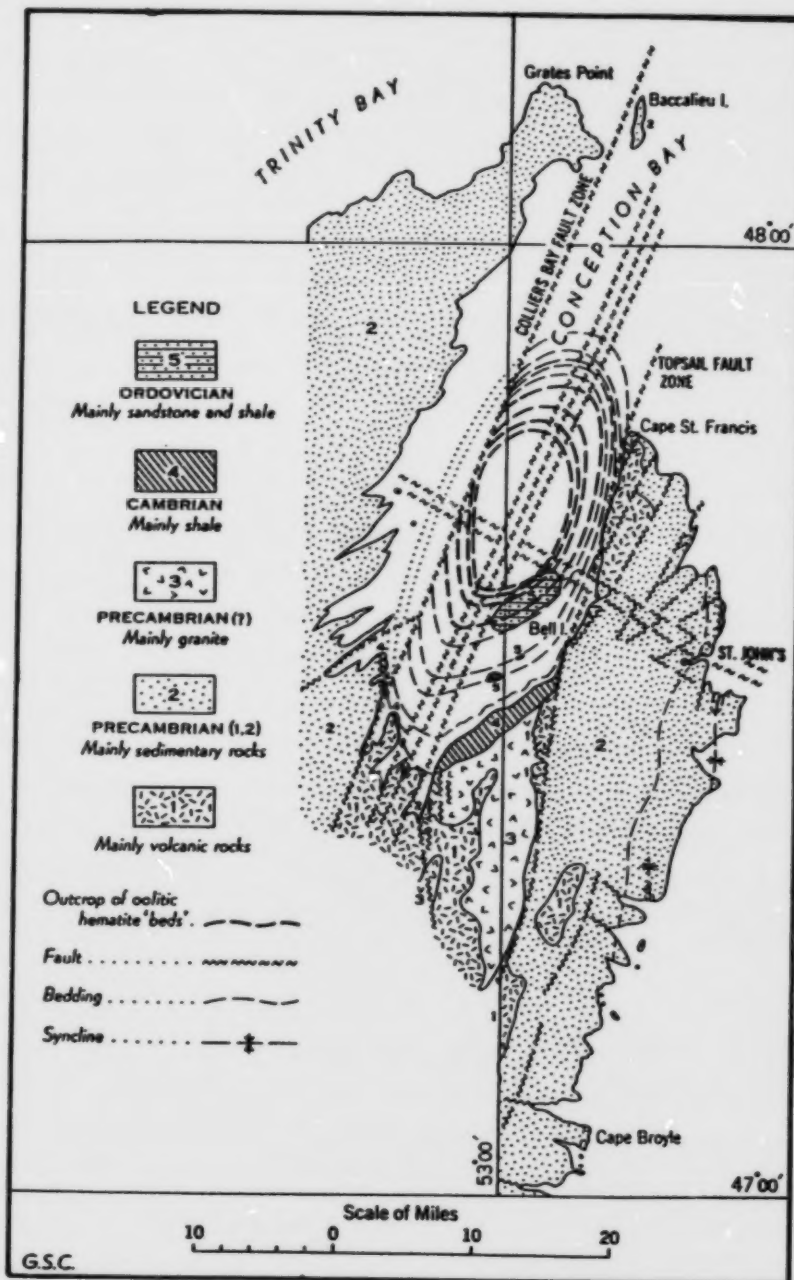
B-3.1.1 Stratigraphy

The Appalachian Orogen in Newfoundland has been divided into four main tectono - stratigraphic zones. Bell Island and the Avalon Peninsula lies within the Avalon Zone which has been interpreted to be an ancient fragment of northwest Africa incorporated into the Appalachian Orogen during Paleozoic times.

Conception Bay is surrounded by highly deformed (folded and faulted) Precambrian to Cambrian aged volcanic and sedimentary rocks (Figure B-2).

Lower Ordovician sedimentary strata are exposed on three islands on the east side of Conception Bay (Kelly's Island, Little Bell Island and Bell Island). They consist of 2400 m of interbedded clastic sediments including the economic deposits of oolitic hematite (iron formation).





SOURCE : Geological Survey of Canada
Memoir 265, E.R. Rose, 1952.

FIGURE B-2
REGIONAL STRATIGRAPHIC SETTING
BELL ISLAND

On Bell Island these strata have been divided into two Groups (note Map 1), based on paleontology and a minor disconformity; namely the Lower Bell Island Group and Upper Wabana Group, (Rose, 1952). The strata dip gently (8 to 12 degrees) to the northwest. The upper unit, the Wabana Group has its base at the top of the Lower (or Dominion) ore bed (see Stratigraphic Chart - Map 1). Both Groups are interpreted as having formed in an intertidal - supratidal environment. Pinching and swelling of sandstone facies above black organic rock shale facies was probably due to tidal channels changing their course (Table B-1). A more detailed description of each Group is presented below.

- Bell Island Group -

The Bell Island Group subcrops beneath approximately 95 percent of Bell Island with an exposed thickness of 365 metres. The northwestern part (centered around the town of Wabana and the mine workings) is underlain by the Wabana Group.

The Beach Formation is exposed along the Southeast Shore and forms the lowermost unit of this Group on the Island. It is comprised of interbedded grey to brown or greenish sandstones and grey to black shales. The strata are in broad lenticular beds of variable thickness, but averaging 0.3 metres. Specific zones composed mainly of sandstone or shale are common and persistent. Generally, the sandstones are fine grained, consisting of rounded to subangular well-sorted quartz grains, with minor amounts of glauconite, chamosite, altered feldspars and ferromagnesian minerals (Rose, 1952). The more ferruginous beds contain siderite with chamosite and glauconite, but carbonate minerals are otherwise absent. The brownish sandstones contain more siderite, the greenish ones, more glauconite and chamosite.

Two minor (uneconomic) iron ore members occur at the top and bottom of the Beach Formation. The lower one is known as the McGraw Ore Member. It is exposed on the southern tip of the island near Chimney Cove. It consists of ferruginous sandstone with some oolitic hematite. The second ore zone, known as the Eastern Head Ore Member (also uneconomic), outcrops between The Bell and Big Head on the western shore of the island. It contains interbedded ferruginous sandstone, oolitic hematite and shales.

TABLE B-1

Depositional Environments of the Bell Island and Wabana Group
 From RN Hiscott 1979, Field Trip
 Memorial University of Newfoundland

FORMATION	INTERPRETED ENVIRONMENT
Gravel Head Formation	Offshore shelf, possibly interdistributary bay or distal prodelta
Upper Ore Beds	Tidal bar
Grebes Nest Point Formation	Shallow subtidal, probably lagoonal
Scotia Formation	Tidal bar
Powers Steps Formation	Shallow subtidal and intertidal flat
44 m	Offshore shelf and prodelta, possibly interdistributary bay
Dominion Formation	Tidal bar
Ochre Cove Formation	Shallow subtidal and intertidal flat, high to moderate tidal range
Redmond Formation	Tidal bar, probably high tidal range
Beach Formation	Shallow subtidal and intertidal flat, high tidal range
30 m	Prodelta and delta front, little or no tidal range
Unexposed	
Kellys Island Formation	Tidal flat and tidal or barrier bar sequences, low tidal range, overlying marine shale

Overlying the Beach Formation is the Redmond Formation which consists almost exclusively of a medium grained, compact, well cemented sandstone interpreted as a migrating offshore sandbar. This unit runs up the centre of the island from Big Head on the west to Redmonds Head on the east side. The sandstone is characteristically whitish in color and visually high in silica. In the upper section of the Formation, is a distinctive thickly bedded white quartzose sandstone which forms a prominent ridge often described as the "backbone of the island". It is referred to as quartzite or orthoquartzite in some reports. The main bed is approximately 80 to 100 metres wide (Anderson and King, 1980). Three quartzite beds have been mapped with interbedded shale beds forming bogs and troughs between the ridges. The bedding planes are irregular and underlating. Jointing is pervasive in the sandstone, although much more dominant in the uppermost bed (Fong and Butler, 1970).

The Ochre Cove Formation overlies the Redmond. It consists largely of shales with minor discontinuous ironstone beds near the top. This is overlain by the Dominion Formation which is also known as the Lower Bed (the lowermost iron ore zone which was mined). It consists of a series of bands of oolitic hematite alternating with fine-grained, cross-bedded sandstone and shale. Contacts between the ore and parting rocks are quite sharp. At the top of the Lower Bed, an erosional disconformity and pyritized graptolites clearly define the base of the Wabana Group.

- Wabana Group -

The Wabana Group underlies the northwestern corner of Bell Island where most of the mining activity took place and the town of Wabana is located. It is subdivided into four Formations which include the Scotia (Middle) ore member and the Upper Ore member as well as a pyrite member. Approximately 183 metres of the Wabana Group is exposed on Bell Island. It is lithologically similar to the underlying Bell Island Group except for the more abundant black shales, oolitic pyrite and other pyritiferous beds as well as the presence of phosphorite beds.

The lowermost Formation of the Wabana Group is the Powers Steps Formations. It consists of fairly thick sections of shale with interbedded sandstones. Within 0.3-3.0 m of its base, just above the Dominion bed lies

an oolitic pyrite zone. Oolite pyrite nodules occur in one to three beds varying in thickness from a few centimetres up to 1.2 metres.

The upper two iron beds, the Scotia (Middle) and Upper Ore Members are located 60 and 80 metres stratigraphically above the disconformity (Map 1). The Scotia Formation immediately overlies the Power Steps Formation. It is texturally and mineralogically similar to the Dominion Formation but richer in iron content. It varies in thickness from 1.5 to 4.5 metres, the average mined width being about 2 metres. The borders of the bed are sharply defined. The lower contact is irregular along channels and depression fillings. The upper boundary is fairly uniform (Gross, 1967).

The oolitic hematite is generally coarser-grained than both the host rock sandstones and shales. The Scotia Formation is coarser-grained than the Dominion Formation. The oolites in the Dominion Formation tend to be somewhat flattened, producing a plane of weakness in the rock. The shaly sandstones are most closely associated with the Scotia (Middle) Bed, whereas the finer-grained shales are more commonly associated with the Upper and Lower Beds.

The Upper Ore Member is separated from the Scotia Formation by the Grebes Nest Point Formation, consisting of approximately 15 metres of mostly shales with minor sandstones, phosphate beds and a chamosite slate bed.

The Upper Ore Member consists of oolitic hematite in an erratic distribution of beds and lenses with intervening sandy and shaly lenses. The iron content is lower than the Middle bed, and more siderite is present as a matrix to the oolitic spherules and also as thin wavy bands along bedding planes.

The uppermost stratigraphic unit exposed on Bell Island is the Gravel Head Formation, consisting of black shales, with minor interbedded sandstone and phosphorite beds. The top of the Wabana Group is not exposed, but diamond drilling from the submarine slopes of the mine has shown that it consists largely of soft, black pyritiferous shale.

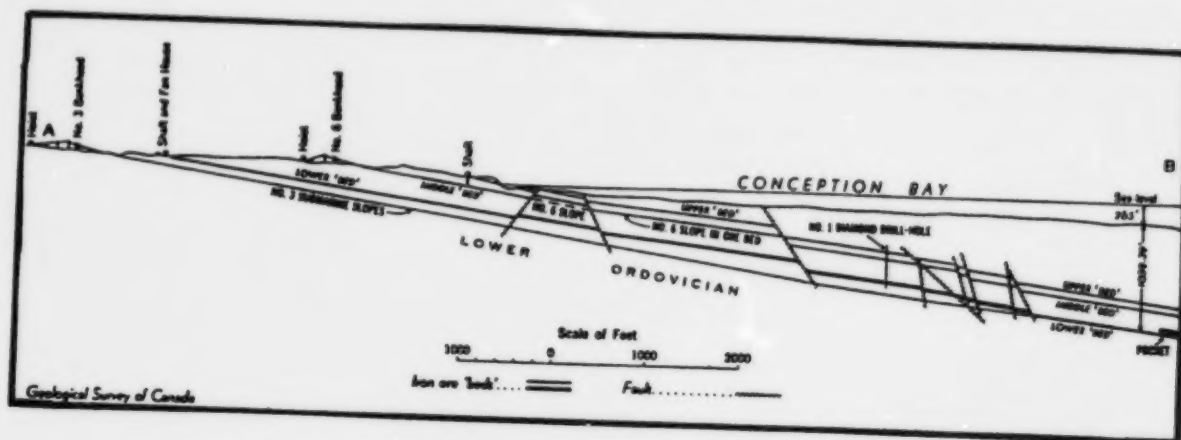
B-3.1.2 Structure

The positioning of Bell Island on the Southeast limb of the Conception Bay Syncline has resulted in a uniform northeast-southwest bedding strike and gentle dips of 5-10° to the northwest over the island (note Figure B-2).

Detailed mapping at the surface and within the mine workings has revealed two prominent sets of faults oriented northwest and northeast, each with their own set of parallel joint systems. Submarine exploration suggests that the Lower Ordovician succession of strata occupies a fault bounded north-northeast trending basin centred three kilometers north of Bell Island (Figure B-2). Norris (1957) noted corrugated surfaces on the fault planes where the dip steepens as faults cross competent ore beds or sandstone, and then flatten to 45 degrees where they cross shale beds. Although movement in more than one direction has occurred on most faults, and both strike-slip and dip-slip movement is evident, it has been determined that northwest-trending faults have right-hand displacement and the northeast-trending faults have left-hand displacement (Gross, 1967). The northeast-trending faults were developed later than the northwest-trending ones. Most movement along faults however involved large blocks of material with little brecciation or contraction of adjacent beds (Ibid.). Displacements on the faults vary from a few centimetres up to a maximum of about 27 metres (Southey, 1969).

Numerous faults are found within the submarine mine workings (Figure B-3). All of the faults appear to be relatively tight and most are dry, although several have been observed to produce very small quantities of fresh and saline water. Many of the faults are filled with calcite.

The two prominent joint sets are essentially parallel in strike to the two fault systems. One joint set strikes at 030 degrees Azimuth, dipping 85 degrees southeast, and the other strikes 110 degrees Azimuth, dipping 85 degrees southwest (Gross, 1967). Both joint sets are equally well developed, especially within the hematite beds, which tends to cause the ore to break into a characteristic regular, angular, relatively smooth sided, rhombic fragments (10 to 25 centimetres wide). The rhombohedral joint system is consistent in attitude throughout the Lower and Middle Beds, with average spacings of 15 to 20 centimetres in the Lower Bed and 8



SOURCE: Geological Survey of Canada
Memoir 265, E.R. Rose, 1952.

FIGURE B-3
CROSS SECTION SHOWING FAULTS AND UNDERGROUND WORKINGS
BELL ISLAND

to 15 centimetres in the Middle Bed (Norris, 1956). Jointing is very extensive and pronounced in all of the ore beds, somewhat less frequent in the sandstones and much less pronounced in the shales.

All joint planes are smooth and mineralized with thin laminae of siderite and calcite, less than 1.5 millimetres thick. Where joints occur in the vicinity of faults, they are slightly more open, up to 6 or 7 millimetres. Within the mine workings the joints persist into the roof and floor sandstone but are poorly developed in the shales between the ore beds. The joint planes rarely extend from roof to floor within the ore beds (Ibid.).

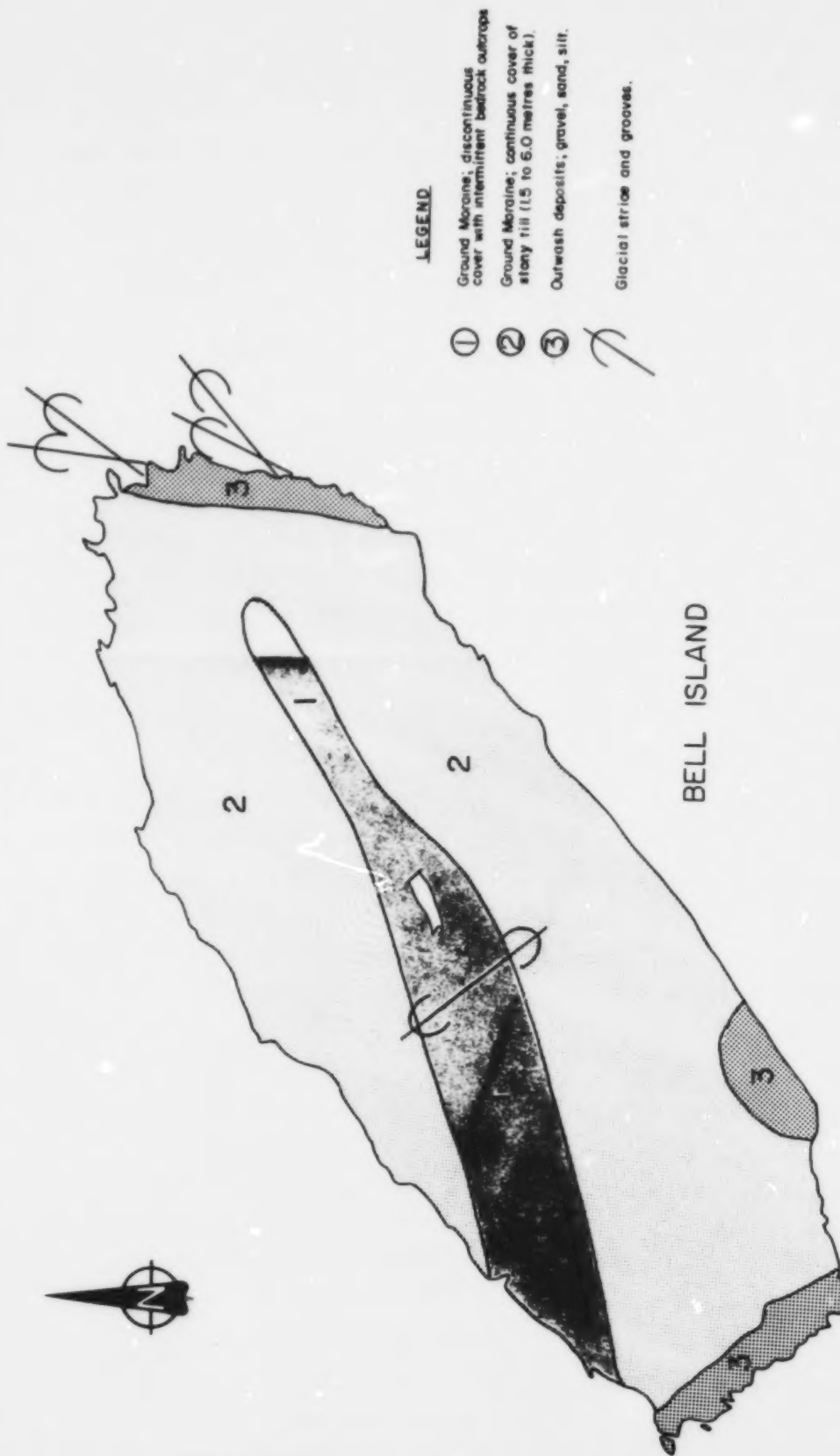
A fracture cleavage is also evidence both parallel with and at an angle to the bedding and is confined mainly to the more incompetent argillaceous rocks of the area. As with the jointing, the cleavage is locally well developed depending on rock character intensity of folding and proximity to faults.

B-3.2 Surficial Geology

The Glacial history of the Avalon Peninsula in general is not well understood. The area was glaciated (possibly more than once) during the Pleistocene Epoch (Henderson, 1972). The major ice flow direction in the immediate area of Bell Island appears to have been northeasterly along Conception Bay. Local glacial striae and grooves on bedrock exposures on Bell Island indicate a northeasterly flow direction; but also a northwest or southeasterly direction. This likely reflects the influence of inferred thin, confluent local ice sheets on both the Carbonear and St John's peninsulas.

B-3.2.1 Ground Moraine (Till)

Much of the Avalon Peninsula, including Bell Island, is covered by a thin discontinuous Quaternary deposit of ground moraine (till) of variable textures and often of uncertain origin. Figure B-4 shows the surficial geology of Bell Island after Henderson (1972). Most of the island is mantled in ground moraine. It is generally a continuous cover (1.5 to 6.9 metres thick), except for a narrow strip extending from Gratton Cove northeastward up the central part of the island. In this area it is a discontinuous moraine, with frequent interspersed outcrops.



SOURCE : Henderson, 1972
GSC Map 1320 A

Scale 1 : 50 000

FIGURE B-4
SURFICIAL GEOLOGY OF BELL ISLAND

The till is typically very stony. The matrix is generally composed of sand and coarse silt, with a small percentage of fines (silt & clay) except in some localities. No grain size analyses were available to quantify the texture further. The till is generally firm, hard and somewhat friable due to the abundance of coarse clasts.

B-3.2.2 Outwash Deposits

Isolated outwash deposits are found near Freshwater, Lance Cove, and north of "The Beach" (Figure 3.2). These areas probably reflect sites where the velocity of meltwater streams was abruptly changed by the topography and interface with the sea. Coarse sand and gravel deposits stretching along the shoreline were laid down in these areas at the edge of the former wasting ice sheet.

B-3.2.3 Organic Terrain (Peat Bogs)

Boggy terrain from NTS 1:25,000 maps and airphotos appears to be widespread, but very localized and probably quite thin.

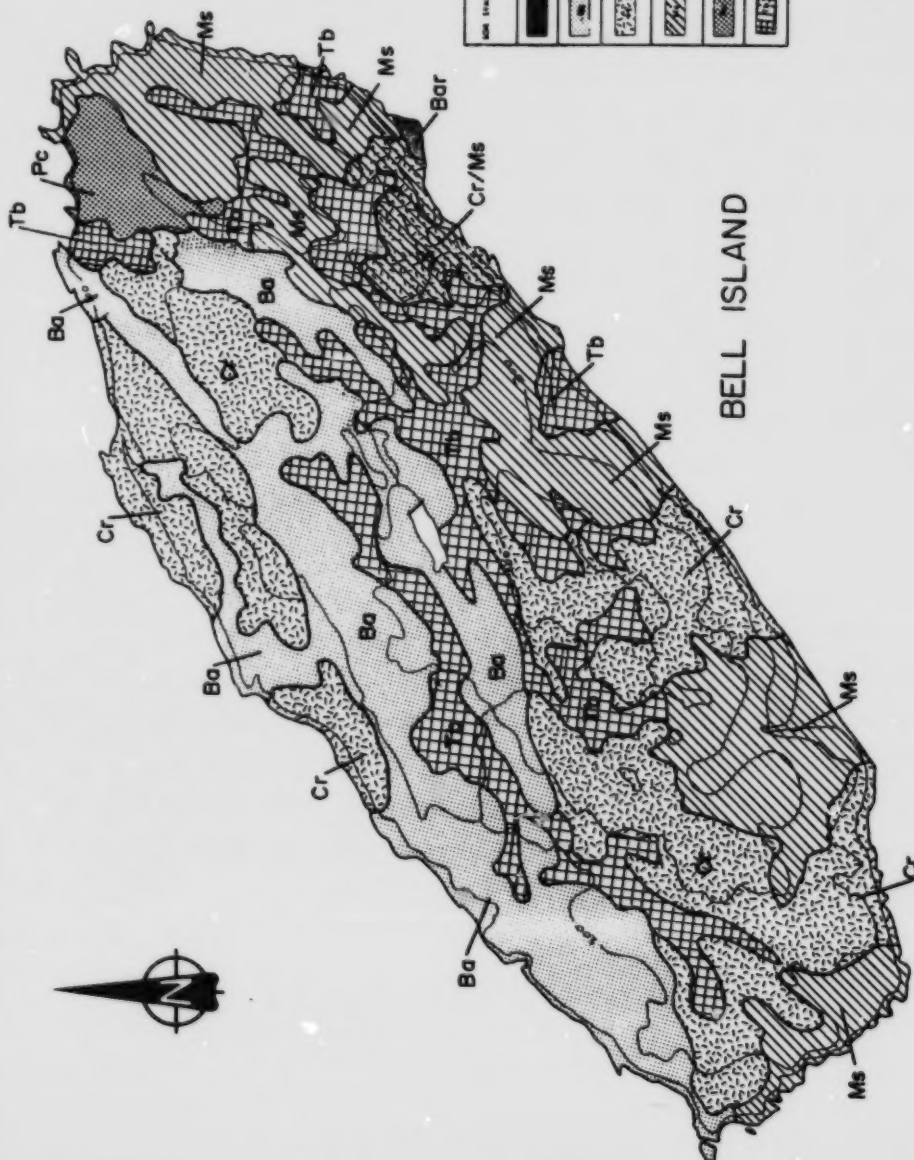
B-3.2.4 Man-Made Deposits

This unit comprises disturbed natural material from past stripping activities as well as new materials deposited over natural materials by man, including stone dumps, aggregate for fill etc. Map 2 indicates major areas where such deposits have been identified.

B-3.3 PEDOLOGY

The soils developed from the Pleistocene deposits have been mapped and described in detail in the Newfoundland Soil Survey Report, No. 3 (Agriculture Canada, 1981). The reader is referred to this reference for a detailed description of each of the soil types, drainage conditions, degree of stoniness and agricultural capability. A summary of the pertinent data is provided below.

There are six different soil series mapped on the island (Figure B-5). They include the Bauline, Cochrane, Manuals, Torbay, Pouch Cove and Barasway Soil Series. All of these soil series are Podzols except for the Barasway, which is an Orthic Regosol, derived from marine gravels, and the



Soil Series	Map Series	Map Code	Parent Material	Soil Series	Soil Series	Soil Series	Soil Series	Soil Series	Soil Series
Ba	1	1	1	1	1	1	1	1	1
Cr	2	2	2	2	2	2	2	2	2
Ms	3	3	3	3	3	3	3	3	3
Tb	4	4	4	4	4	4	4	4	4
Pc	5	5	5	5	5	5	5	5	5
Bar	6	6	6	6	6	6	6	6	6

NOTES

* Capability Class for Agriculture:

Degree of limitation to use becomes more severe from Class 1 to Class 7.

Class 1-3: Soil capable of sustaining common crops grown in area.
 Class 4: Marginal for sustained arable agriculture.
 Class 5: Suitable only for use as permanent pasture and hay.
 Class 6: Not suitable for natural pasture.
 Class 7: Not suitable for agriculture.

Scale 1: 50 000

SOURCE : Agriculture Canada
 Soil Survey Report No. 3
 (Newfoundland Soil Survey, 1981)

FIGURE B-5
 SOILS OF BELL ISLAND

Torbay which is a Rego Gleysol, derived from a stony, sandy loam till. All of the soils are olive to dark grey in color, typically firm and very stony to excessively stony, which severely restricts their potential for agricultural use. Drainage of the soils vary but they are generally well to moderately well drained. The Torbay and Pouch Cove soils are poorly drained.

Podzol soil profiles in Atlantic Canada become notably indurated and/or cemented by a combination of Duripans, Fragipans, Ortsteins and Ironpans (G. Beke, pers comm). These horizons are due in part to cementation by silica, iron and/or manganese or a high percentage of silty or very fine sand.

The four podzol soil types cover by far the most extensive area of Bell Island (Figure B-5). The Bauline Soil Series occupies the northwestern side of the island. This soil is derived from shallow, stony glacial till interspersed among extensive bedrock outcrops. It is a sandy loam which is well drained on steep slopes, but wet conditions prevail in small valleys and depressions. Severe limitations on agricultural use of this soil derive from its stoniness, exposure to wind, topographic and bedrock conditions.

The Cochrane Soil Series occupies central and southeastern parts of the island. It is a dark olive grey, exceedingly stony loam type of acidic soil which is moderately well drained. This soil is typically found on undulating or hilly terrain. Most farming on the adjacent Avalon Peninsula is carried out on the Cochrane Soil Series, but it is limited on Bell Island because of excessive stoniness and intermittent bedrock outcrops.

The Manuals Soil Series occurs in the southeastern parts of the Island. It is an acidic clayey soil, dark greyish-brown in color, moderately stony and moderately to well drained. This soil has the best potential of all of the Soil Series in Bell Island for agricultural use.

The Pouch Cove Soil Series is an olive colored, very stony loam. It is restricted to an area near Freshwater Cove on the northern tip of Bell Island.

B-3.4 Physiography

The geological processes previously discussed resulted in the present geomorphic expression of Bell Island and the surrounding landscape. The entire Avalon Peninsula exhibits the Appalachian northeast-southwest trending structural grain. Superimposed on this was differential erosion associated with subaerial exposure since at least the Mesozoic. This denudation reduced the terrain of the Avalon Peninsula to a number of level peneplains. Glacial erosion and deposition had only a minor secondary effect; therefore, relief is primarily bedrock controlled.

The surface of Bell Island is characterized by a smooth, undulating topography with variation in relief ranging from 30-137 m a.s.l. The higher relief is found predominately in a northeast trending ridge located near the southwest end of the island. Unexpectedly, this does not correspond with the Redmond Formation.

The quartzite zones of the Redmond Formation or a group of long arcuate ridges running along the central long axis of the island. The combination of the gentle northwest dip and intervening shales creates a characteristic dip slope and cuesta topography.

The shoreline, however, is quite the opposite to the surface relief being characterized by shear cliffs around the entire perimeter. They are higher on the southeast side than the northwest side due to bedrock dip. There are only a few locations on the entire island where the land naturally slopes gently to the shoreline allowing access. The gently sloping bedrock exposed in these cliffs gives the island a "layer cake" appearance. These actively eroded cliffs are characteristic of a "shoreline of submergence" created by a rising sea level post glaciation.

B-3.5 Long Term Trends

There appears to be only one major "long" term geological process of practical importance to this study, that being a rise in sea level at a general rate of approximately 0.3 m per century (Grant, 1975).

B-4.0 CLIMATE

B-4.1 Introduction

The Atlantic region is generally situated where practically all cyclonic storms of North America leave the continent. In combination with the proximity of the Atlantic Ocean this gives the region a humid continental climate.

There are 17 climate stations located on the Avalon Peninsula of Newfoundland that have complete records (Figure B-6). The stations located nearest to Bell Island are those at St. John's Airport (St. John's A) and Seal Cove. The stations are 16 and 22 kilometres respectively from Wabana, Bell Island.

With 39 years of records, the station at St. John's Airport has one of the most complete set of records on the Peninsula. This station is also the closest to Bell Island. However, the climate at the Airport is significantly different from that at Seal Cove, as exemplified by an annual average snowfall at the airport of 359.4 centimeters (over 88 days) versus 185.9 cm (over 22 days) at Seal Cove.

The airport's location on the lee shore of the east coast of Newfoundland, places it in a heavy snowfall area (Hare and Thomas, 1974). For this reason, it is felt that despite the shorter distance from the Airport to Bell Island and the greater number of years of record available, the climatic data available at the Airport may not represent the climate of Bell Island. The climate at Seal Cove appears to be much more influenced by the ocean than the climate at the Airport. It is felt that the climate at Bell Island would be similar. Accordingly, climatic data from Seal Cove will be used for most of the following descriptions.

B-4.2 Precipitation

The 1951-1980 normal total annual precipitation at Seal Cove is 1272.9 mm (Table B-2). Since only 16 years of data are available at Seal Cove, the averages of climatic data from the station have been adjusted to make them comparable with those from full-period, 30 year stations (AES per comm). The standard deviation for the normal total annual precipitation is 166.7 mm. Of the seventeen climatic stations on the Avalon Peninsula, Seal Cove has close to the average annual total precipitation (1275.2 mm) for the Peninsula (Banfield 1981).

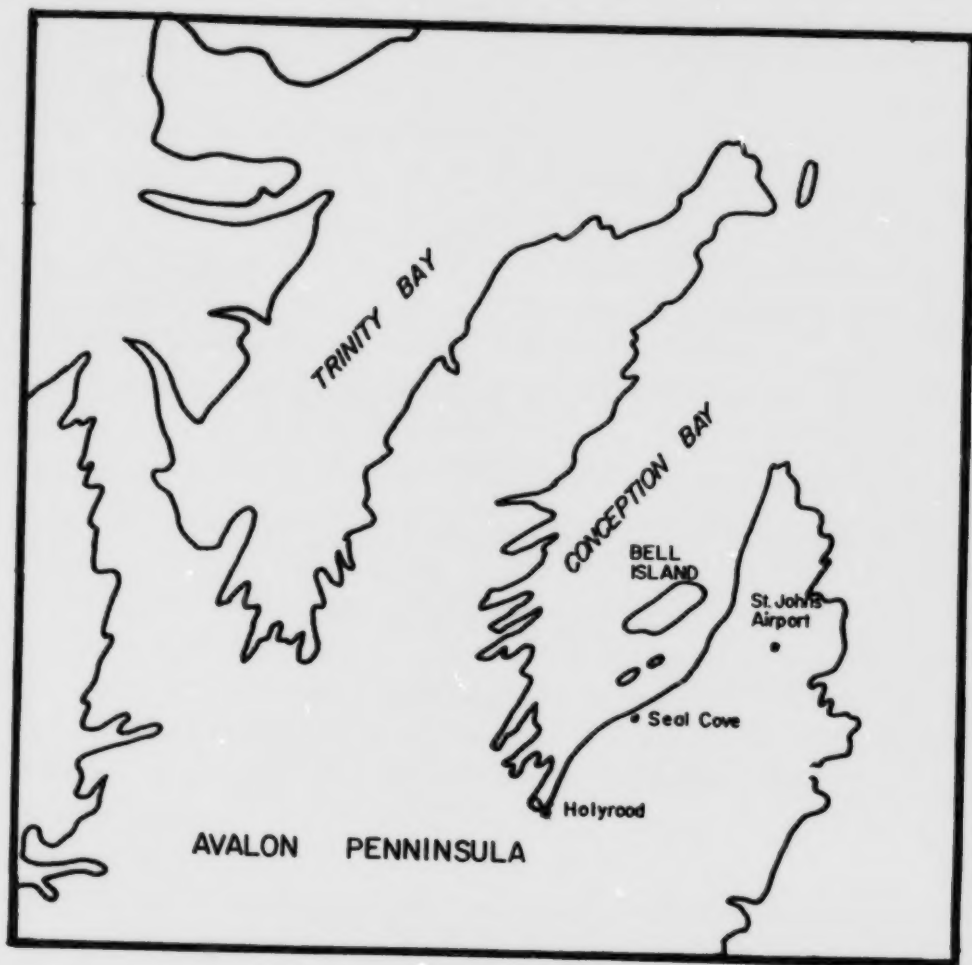


FIGURE B-6
LOCATION OF PERTINENT CLIMATIC STATIONS

TABLE B-2
1951-1980 Normals
Seal Cove

Courtesy of Atmospheric Environment Service
Environment Canada

SEAL COVE 47° 27'N 53° 4'W 15 m																	
Daily Maximum Temperature	0.8	0.6	2.7	6.7	11.6	17.3	21.9	21.0	17.2	12.1	7.9	3.0	10.2	8	Température Maximale Quotidienne		
Daily Minimum Temperature	-6.5	-6.9	-4.3	-1.0	2.2	6.7	11.2	11.9	8.1	4.1	0.9	-3.9	1.9	8	Température Minimale Quotidienne		
Daily Temperature	-2.9	-3.1	-0.8	2.9	6.9	12.1	16.6	16.5	12.7	8.1	4.4	-0.5	6.1	8	Température Quotidienne		
Standard Deviation, Daily Temperature	1.9	2.2	1.7	1.2	1.4	1.6	1.4	1.7	1.0	0.8	1.5	2.1	0.7	4	Écart Type de la Température Quotidienne		
Extreme Maximum Temperature	15.0	14.4	16.7	18.3	26.1	30.0	31.7	31.0	26.7	27.8	21.1	15.6	31.7		Température Maximale Extrême		
Years of Record	18	18	18	18	18	17	18	18	19	19	19	19	19		Années de Relèves		
Extreme Minimum Temperature	-20.6	-26.7	-18.3	-16.0	-7.8	-4.4	0.0	0.0	-1.1	-5.6	-16.0	-18.9	-26.7		Température Minimale Extrême		
Years of Record	18	18	18	18	18	18	18	18	18	18	19	19	19		Années de Relèves		
Rainfall	87.8	75.5	81.5	78.9	74.5	73.6	65.7	100.1	93.2	128.1	114.7	99.3	1072.9	8	Chutes de Pluie		
Snowfall	51.2	46.5	35.9	9.9	1.6	0.2	0.0	0.0	0.0	0.7	6.6	33.3	185.9	8	Chutes de Neige		
Total Precipitation	137.3	124.6	121.2	95.4	75.9	73.6	65.7	100.1	93.2	128.8	121.2	135.9	1272.9	8	Précipitations Totales		
Standard Deviation, Total Precipitation	45.7	63.3	39.5	38.4	24.4	30.9	33.4	76.0	41.0	49.3	45.5	54.0	166.7	4	Écart Type des Précipitations Totales		
Greatest Rainfall in 24 hours	90.7	61.7	53.3	62.2	31.0	55.4	53.8	71.4	66.1	52.8	66.8	79.2	90.7		Chute de Pluie Record en 24 heures		
Years of Record	19	18	18	18	18	18	19	18	19	18	20	19	19		Années de Relèves		
Greatest Snowfall in 24 hours	36.1	43.2	38.1	38.1	10.2	5.1	0.0	0.0	0.0	10.2	27.9	29.5	43.2		Chute de Neige Record en 24 heures		
Years of Record	18	16	18	17	17	19	20	19	20	20	20	19	19		Années de Relèves		
Greatest Precipitation in 24 hours	90.7	61.7	53.3	62.2	31.0	55.4	53.8	71.4	66.1	52.8	69.9	79.2	90.7		Précipitation Record en 24 heures		
Years of Record	19	17	18	18	18	18	19	18	19	18	20	19	19		Années de Relèves		
Days with Rain	7	5	7	9	10	8	8	10	10	14	11	9	106	8	Jours de Pluie		
Days with Snow	6	5	4	2	0	0	0	0	0	0	1	4	22	8	Jours de Neige		
Days with Precipitation	12	11	12	11	11	9	8	10	10	14	12	13	133	8	Jours de Précipitation		

Generally the precipitation in the area is well distributed throughout the year. Minimums at Seal Cove occur from April through September with the months of May, June and July having the lowest amount of precipitation. During these months the concentration of low pressure centered over the St. Lawrence Valley leaves the Atlantic Provinces under the predominate influence of winds from the south, southeast or west. Major rainfalls during this period result primarily from remnants of hurricanes passing through the region and from thunderstorms. Thunderstorms occur on the average of five days a year in Newfoundland (Hare and Thomas, 1974). Maximum precipitation occurs during the late fall and winter seasons because of more frequent and intense cyclonic activity.

In Seal Cove, approximately 17% of the precipitation originates as snow, falling predominately during the December to April period. The average of 22 days with snowfall each year is significantly less than at St. John's Airport. As the Seal Cove Station is located on the coast at an elevation of 15 m, winter storms sweep in warmer, maritime air and the precipitation falls as rain. The higher elevation (140 metres) at the airport results in cooling of the air mass and causes precipitation to fall as snow. Rainfall occurs all year round in Seal Cove. Freezing rainstorms are more frequent in Newfoundland than in any other part of Canada (Hare and Thomas, 1974).

B-4.3 Air Temperature

The mean (1951-1980 normal), annual daily air temperature at Seal cove is 6.1°C with a standard deviation of 0.7°C (Table B-2). The equivalent temperature at the St. John's Airport is 4.8°C with a standard deviation of 0.7°C.

At Seal Cove, the minimum monthly temperature (-3.1°C) occurs in February. Mean monthly temperatures below freezing occur from December to March inclusively. Maximum mean monthly temperatures occur in July (16.6°C) and August (16.5°C).

In winter, from January to March, pack-ice frequently moves in from the sea and lodges along the Atlantic coast of Newfoundland. The arrival of spring is frequently retarded by the cooling presence of the pack-ice. there is a 50 percent probability of frost on any night until

the first week of June (Hare and Thomas, 1974). The eastern coast of Newfoundland is markedly cooled in the summer by the cold water of the Labrador current. In the fall, oceanic water is warm relative to the air and holds back the onset of winter for a few weeks.

The prevailing circulation of continental air masses from the west allows much wider fluctuations in temperatures than are found in a true maritime climate. There is a fairly regular and marked day to day change in winter temperatures caused by Arctic or Continental air being replaced briefly by Maritime air with the passage of storm systems every two or three days (Hare and Thomas, 1974).

Fog is most common in Newfoundland in the spring and early summer. It is most evident along the Atlantic coast where the adjacent seawater is relatively cold due to the influx of water from the Labrador current.

B-4.4 Evaporation

The mean annual lake evaporation (Table B-3) for the St. John's Airport has been calculated using 30 years of evaporation pan data (1951-1980), (Environment Canada (1984)). The annual calculated lake evaporation is 407.7 mm. Evaporation apparently commences in June and is at its maximum in July.

B-4.5 Evapotranspiration

The Avalon Peninsula and Bell Island lie within the boreal forest region. Characteristic trees of the Avalon Peninsula include White Spruce, Black Spruce, Tamarack, Balsam Fir and Jack Pine. Other, less important, tree species include Eastern White Pine, Red Pine, Yellow Birch, Black Ash, Eastern White Cedar and Trembling Aspen (Hosie, 1969). Shrubbery include Labrador Tea, Dwarf Birch, low sweet blueberry, cranberry and mooseberry (Mednis, 1981).

Utilizing 1941-1970 normalized data and assuming a 200 mm soil deficiency, the annual potential evapotranspiration calculated using the Thornthwaite method (McKay, G.A., 1970) at Seal cove is 514 mm (Table B-3). The actual annual evapotranspiration, as calculated by means of a climatic water balance is 516 mm. The climatic water balance calculation was completed by Environment Canada (Phillips, 1976).

TABLE B-3
MEAN MONTHLY EVAPORATION AND EVAPOTRANSPIRATION RATES FOR SEAL COVE

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	ANNUAL
Calculated Lake Evaporation (mm) means 1951-80 St. John's A.						100.3	129.4	98.8	79.2				407.7
Potential Evapotranspiration (mm)	0	0	0	17	50	91	122	112	72	43	24	0	514
Actual Evapotranspiration (mm)	0	0	0	13	50	89	110	111	72	43	24	0	516
Moisture Deficit (mm)	0	0	0	0	0	2	12	1	0	0	0	0	15
Moisture Surplus (mm)	0	0	0	312	38	0	0	0	0	18	102	137	608

* Environment Canada, 1984. Canadian Climate Normals Soil Temperature, Lake Evaporation Days with ..., 1951-1980. Volume 9. Canadian Climate Program, Atmosphere Environment Service, Ottawa, 101 pp.

NOTE: Climate water balance calculated by Thornthwaite Method - Assumes water holding capacity 200 mm.

The Thornthwaite method does not account for the presence of fog and the high relative humidity near the ocean. Smith (1964) found that in Maritime climates the annual Thornthwaite potential evapotranspiration was consistently excessive; the 26-year mean annual value being 123% of evaporation pan data.

The resultant average annual soil moisture deficit as calculated by the climatic water balance (Phillips, 1976) is only 15 mm, 12 mm of which occurs in July. The annual moisture surplus is 608 mm, most of which occurs in April.

B-4.6 Wind

The average wind speeds and percent frequency at St. John's Airport, based on the 1955-1980 period, are given in Table B-4. It indicates that the prevailing wind direction is generally from the west southwest.

The prevalent westerly winds are produced between the upper air low pressure centered over the eastern Canadian arctic archipelago and the Bermudian and northeast Pacific subtropical high pressure cells (Banfield, 1981).

During the April to October period at the St. John's Airport, the prevailing wind direction is from the west southwest. Mean wind speed during this period ranges from 24.4 to 23.8 km/h. During the winter (November - March) the prevailing wind direction is from the west. During this period wind speed is slightly higher. Mean wind speed ranges from 25.2 to 27.5 km/h.

B-4.7 Long Term Trends

A running decadal means analysis was conducted for this report on the total precipitation data collected at the St. John's Airport since 1941. No consistent long term trend in total precipitation was observed (Figure B-7).

TABLE B-4
Wind Speed and Direction
St. John's A, Nfld.

Courtesy of Atmospheric Environment Service
Environnement Canada

ST JOHN'S A NFLD.

PERIOD 1955-80 PERIODE

Lat. 47°37'N Long. 052°45'W

Elevation 140 m Altitude

	JAN JANV	FEB FEV	MAR MARS	APR AVR	MAY MAI	JUN JUN	JUL JUL	AUG AOUT	SEP SEPT	OCT OCT	NOV NOV	DEC DEC	YEAR ANNUEL	
PERCENTAGE FREQUENCY														
														FRÉQUENCE EN %
N	4.8	5.7	7.0	7.4	8.9	6.2	2.3	3.8	5.2	5.8	4.7	8.0	6.3	N
NNE	4.2	4.1	7.0	6.8	6.2	6.3	2.8	2.9	4.7	3.1	3.8	3.0	4.3	NNE
NE	3.4	3.8	6.5	4.8	6.1	4.6	3.8	3.3	3.8	2.2	3.5	2.8	3.8	NE
ENE	2.3	2.6	3.2	2.8	2.8	2.2	1.8	1.9	2.0	1.8	2.2	1.9	2.2	ENE
E	2.7	2.8	3.2	3.6	3.9	2.2	1.8	2.1	2.2	2.2	3.2	2.3	2.7	E
ESE	2.1	2.6	2.8	2.9	3.2	2.3	2.3	2.2	1.8	1.3	2.2	1.7	2.3	ESE
SE	3.4	3.7	3.6	4.6	4.9	4.4	4.6	3.9	3.2	2.8	3.2	2.8	3.8	SE
SESE	3.8	3.9	3.8	4.3	4.4	4.2	4.8	4.8	3.4	4.0	3.9	4.1	4.1	SESE
S	5.9	6.2	8.4	8.6	6.1	6.1	7.8	7.1	6.4	7.1	9.2	8.4	8.8	S
SSW	4.8	4.7	4.1	4.1	4.8	5.8	8.9	7.0	8.4	8.9	7.0	8.8	8.8	SSW
SW	7.4	7.7	6.9	7.3	7.3	9.7	12.7	12.4	10.7	9.4	9.4	8.8	9.1	SW
WSW	11.8	10.4	12.7	14.5	17.3	23.4	28.2	23.8	19.0	16.8	12.5	11.4	18.6	WSW
W	18.7	17.6	14.2	12.0	12.9	13.1	18.1	14.4	18.1	15.7	14.1	17.2	15.1	W
WNW	11.9	10.9	7.8	5.6	3.8	3.7	2.4	3.3	5.5	6.5	6.7	10.1	8.8	WNW
NW	6.3	6.7	8.5	8.8	4.2	3.1	2.1	3.1	4.3	7.2	8.4	8.7	8.3	NW
NNW	4.5	5.8	4.8	6.5	4.4	2.9	2.7	2.8	3.8	6.0	4.3	6.0	4.4	NNW
Calm	2.4	1.8	2.0	1.8	2.1	2.1	1.9	1.6	1.9	2.2	2.2	2.1	2.0	Calm

MEAN WIND SPEED IN KILOMETRES PER HOUR														
VITESSE MOYENNE DES VENTS EN KILOMÈTRES PAR HEURE														
N	27.8	26.8	26.5	27.8	27.0	21.2	18.0	22.0	22.3	25.5	25.9	28.4	24.9	N
NNE	27.7	25.9	26.1	25.1	22.0	19.8	18.9	19.5	21.8	28.6	28.1	27.2	23.9	NNE
NE	27.2	25.3	28.0	19.9	18.0	17.3	14.1	17.8	17.8	27.2	23.3	22.4	20.9	NE
ENE	29.3	28.9	29.1	21.8	18.4	17.4	14.8	17.9	18.4	21.0	21.8	21.9	21.4	ENE
E	25.1	25.5	23.3	19.3	17.2	15.2	12.9	17.4	18.3	19.7	22.8	25.1	20.0	E
ESE	25.6	27.8	23.2	19.2	17.0	15.0	18.0	18.8	18.8	20.8	23.0	28.9	20.8	ESE
SE	27.6	28.3	23.9	20.3	17.8	16.4	18.8	17.3	18.7	22.0	23.9	27.8	21.4	SE
SESE	29.3	27.8	28.3	24.4	20.5	18.0	18.9	19.7	20.9	25.0	25.2	29.8	23.9	SESE
S	28.1	25.6	27.6	24.6	22.0	21.4	20.0	20.1	22.2	24.8	27.8	28.8	24.4	S
SSW	24.0	25.9	25.7	24.1	22.8	21.6	21.8	21.1	22.2	22.2	25.7	23.8	23.4	SSW
SW	24.8	25.5	25.5	25.2	24.7	24.3	23.8	22.8	22.2	24.3	25.2	24.2	24.2	SW
WSW	29.9	29.0	29.7	27.0	28.9	27.2	28.4	24.0	24.7	28.0	27.8	28.6	27.1	WSW
W	31.0	30.8	29.7	24.8	25.5	25.0	24.1	23.9	24.8	28.8	26.7	29.8	28.8	W
WNW	29.3	30.8	28.8	25.3	23.9	22.0	19.0	20.0	22.8	24.3	26.3	28.7	25.1	WNW
NW	23.8	27.2	28.4	27.0	25.0	22.4	20.0	20.8	21.8	22.8	24.4	24.8	23.9	NW
NNW	27.9	30.2	28.5	29.3	27.7	22.9	23.7	21.7	22.8	26.2	27.1	28.4	28.0	NNW
All Directions														
	27.6	27.6	26.9	24.4	22.9	22.2	21.4	21.2	22.1	23.8	25.2	28.8	24.3	Toutes directions
Maximum Hourly Speed														
	120	137	121	63	101	74	87	74	87	103	105	87	137	Vitesse horaire maximale
	WSW	NNE	NW	SW	N	NW	WSW	N	S	W	WSW	W	NNE	
Maximum Gust Speed														
	187	193	148	159	148	108	107	113	122	122	145	183	193	Vitesse maximale des rafales
	WSW	SW	NNW	SW	N	ENE	SE	W	SW	WSW	SW	SW	SW	

Height of anemometer 10.1 m hauteur de l'anémomètre

STATION INFORMATION

The Atlantic Ocean lies 0.5 km east, Conception Bay 10 km west, and the city of St. John's 5-8 km south, southeast of the station. Windsor Lake is located approximately 1.6 km southwest. The terrain in the east quadrant gradually slopes down to the Atlantic. From south through west to north, there are a large number of hills within 4-8 km of the station ranging in height from 182-244 m.

DONNÉES RELATIVES À LA STATION

L'océan Atlantique s'étend à 0.5 km à l'est, à 10 km à l'ouest s'ouvre la Baie Conception et à 5-8 km au sud-sud-est se trouve la ville de St-Jean. Le lac Windsor, est situé à environ 1.6 km au sud-ouest. Dans le quadrant est, le terrain descend progressivement jusqu'à l'Atlantique. Du sud à l'ouest direction nord se trouvent un grand nombre de collines à une distance de 4-8 km de la station, culminant à 182-244 m.

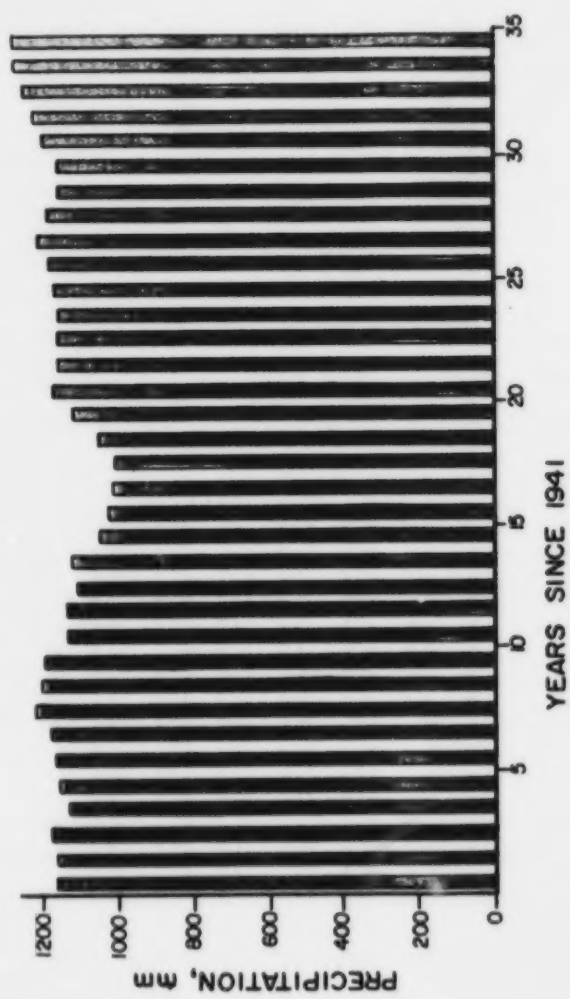


FIGURE B-7
RUNNING DECADEL MEANS OF ANNUAL PRECIPITATION AT ST. JOHN'S AIRPORT

B-5.0 HYDROLOGIC CYCLE

B-5.1 Definition

As indicated in Section A-3.0 the approach taken in this report is to describe the fresh waters of the island in terms of systems or cycles; of which the hydrologic cycle is one. One of the ways of classifying these systems is in terms of structure. The hydrologic cycle is a "cascading system", being defined as a structure within which the output from one subsystem forms the input for the next subsystem and within which a regulator may operate either to divert a part of the input of mass or energy into storage or to create a throughput, producing the system output.

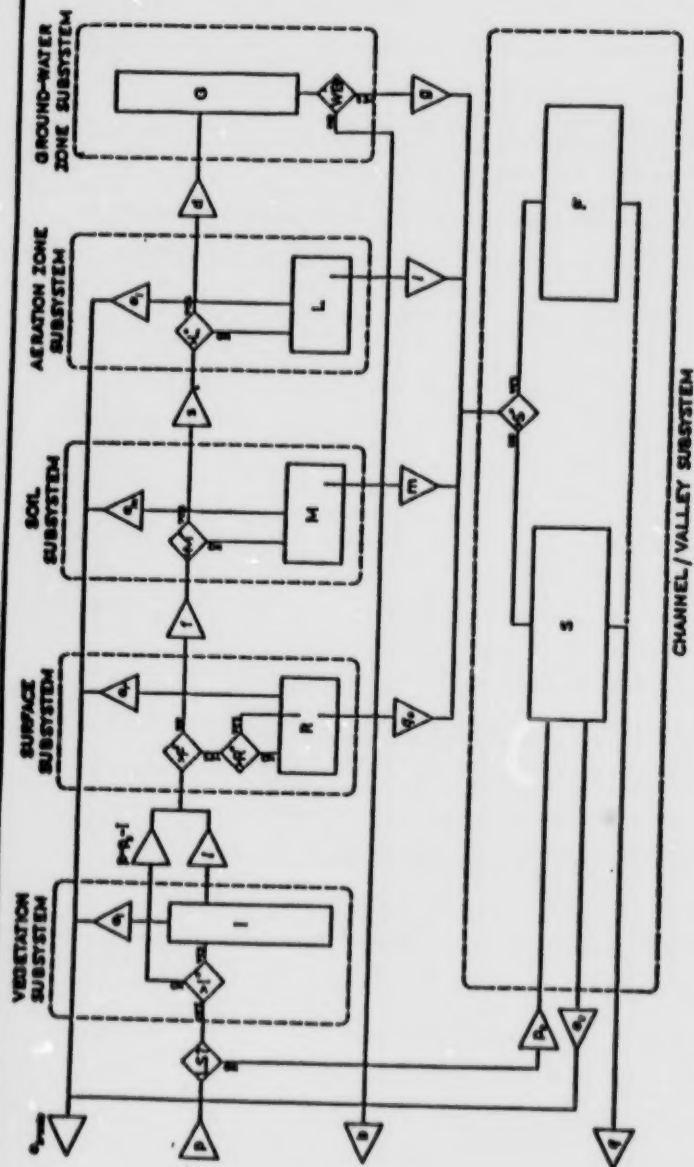
The hydrologic cascade is illustrated as a canonical structure in Figure B-8. The description of the cycle within Bell Island is divided into a morphological description of the components of surface waters and groundwater followed by a discussion of flow throughout the cycle.

B-5.2 Surface Water Hydrology

B-5.2.1 Introduction

There are a total of 19 watersheds exhibiting defined channels over the island based upon 1:25,000 scale mapping (note Figure B-9). In addition, there is a portion of the island identified as shore drainage, which is located in proximity to the coast and does not exhibit defined watercourses. All watersheds on the island drain directly into the saline waters of Conception Bay. There are no estuarine environments.

Bell Island is located within the Atlantic Ocean Basin, area 103, specifically watershed 22M of Environment Canada's national hydrometric numbering system. However, there has been no formal hydrometric numbering system applied to the island's watersheds. For this report they have been identified utilizing an alphabetical code from A-S inclusive (note Figure B-9) moving in a clockwise direction from the northeast end. The main brook which has been dammed for water supply has been named Freshwater Brook for subsequent referral. In addition, the watershed encompassing Wabana and the strip mining area has been named the Wabana Watershed.

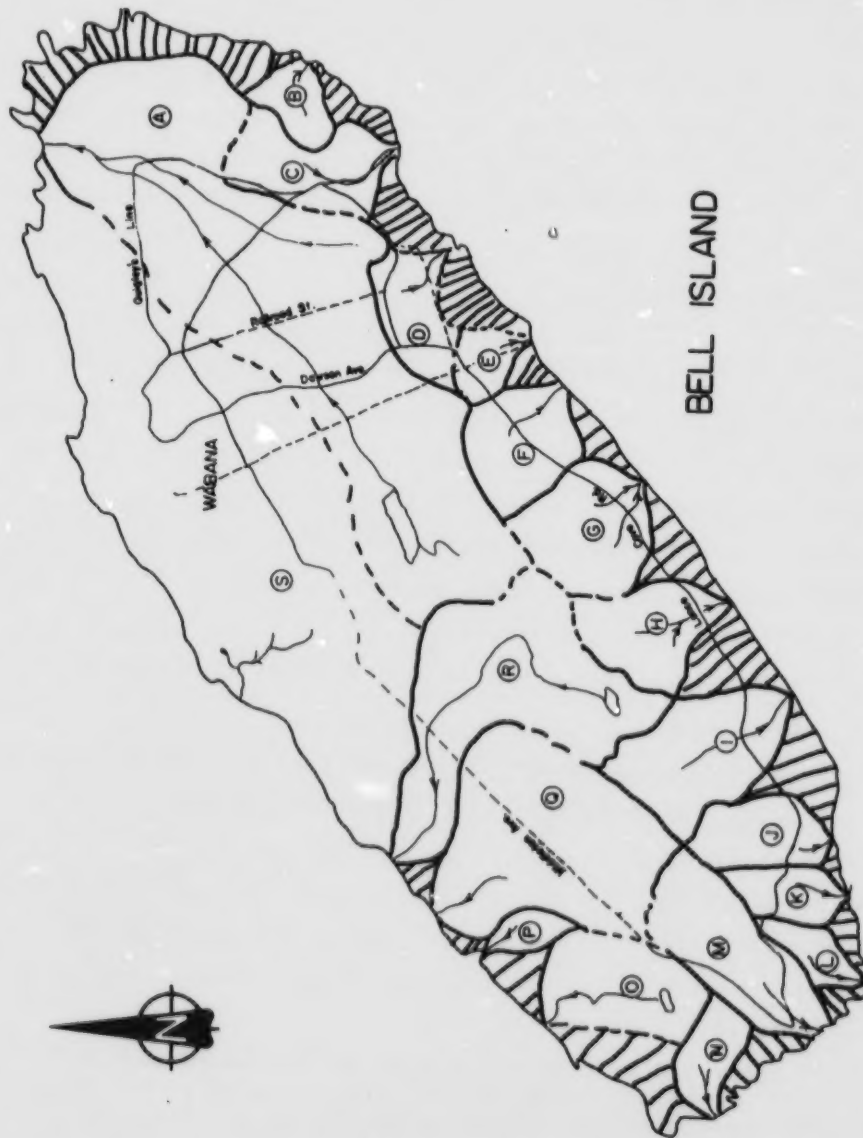


p - precipitation
 ps - stream/lake surfaces
 I - interception storage
 F* - infiltration capacity
 R* - surface detention
 q0 - channel runoff
 er - evaporation
 ei - evapotranspiration
 eg - evapotranspiration from water surfaces

em - evaporation from soil
 ei - evaporation from aeration zone
 f - infiltration below the surface
 M* - field moisture capacity
 M - soil moisture storage
 S - aeration zone subsystem
 m - throughflow
 L - aeration zone storage
 I - interflow
 d - deep percolation

G - groundwater storage
 S* - channel capacity
 qb - bankfull discharge
 S - channel storage
 q - stream discharge
 F - floodplain storage

FIGURE B-8
A CANONICAL REPRESENTATION OF THE BASIN HYDROLOGICAL CYCLE



- LEGEND
- (A) Pertinent watershed areas
 - ||||| Shore drainage
 - Watershed boundaries (defined, approximate)
 - Defined surface channels

Scale 1:50 000

FIGURE B-9
SURFACE WATERSHEDS OF BELL ISLAND

B-5.2.2 Drainage Basin Morphology

The most notable characteristic of the watersheds is their relatively small size, generally less than 1 km² (Table B-5). The two largest (Freshwater Brook and Wabana) are only 5.59 and 6.70 km² respectively.

Preglacial drainage patterns were probably simple, consisting of streams which radiated outwards from the bulk of the Southern Avalon. Prior to the advance of the Wisconsin ice sheet, the declining sea levels would have allowed drainage patterns to extend far out to the north, south and east of present day coastlines, over what is now the continental shelf. After recession of the ice sheet these systems were gradually submerged as a result of post glacial sea level rise over the past 10,000 years. What is present today are only the remnant low order tributaries located in the headwaters of once larger rivers.

Assessment of the drainage patterns in Freshwater Brook indicates a close relationship with primarily bedrock strike. This watershed is located over the Redmond Formation on the northeast half of the Island. This, however, does not apply over the southwest half, as drainage patterns in watersheds N through R inclusive cross cut this feature.

Watersheds B-L inclusive are small and drain off the central ridge. This trend is positioned at right angles to strike, and at times coincident with the NW-SE trending fault set.

The natural drainage pattern in Watershed S has been destroyed by strip mining and urbanization.

The drainage pattern over the island may therefore be defined as primarily dendritic with a secondary trellised/parallel pattern except in S where it is defined as deranged.

Drainage densities of 0.43 - 2.86 indicate that all watersheds are poorly drained. In addition, the texture ratios are all low; thereby defining the overall density as coarse textured (Figure B-11). These low values are believed to be a function of:

- . the small watershed size, which limits the volume of water moving through the basin and necessitates accounting for the critical belt of no erosion around the watershed divide
- . the very low frequency of high intensity rainfall associated with thunderstorm activity

TABLE B-5
DRAINAGE BASIN MORPHOLOGY BELL ISLAND

Watershed Designation	Total ¹ Area (km ²)	Shreve Stream Order No. for Main Stream at mouth	Stream ² Length (km)	Drainage Density (km/km ²)	Texture ³ Ratio (mile ⁻¹)
A	5.59	4	7.38	1.32	8.3
B	0.29	1	0.50	1.72	14.1
C	0.63	1	1.00	1.58	7.7
D	0.57	2	1.13	1.98	8.3
E	0.20	1	0.25	1.25	5.0
F	0.59	1	0.75	1.27	4.6
G	0.76	2	1.00	1.32	5.9
H	0.63	2	1.13	1.79	5.0
I	1.03	1	0.95	0.92	4.8
J	0.46	1	0.50	1.09	4.6
K	0.28	1	0.38	1.36	8.3
L	0.22	1	0.63	2.86	4.0
M	0.96	1	0.63	0.66	7.7
N	0.34	2	0.88	2.59	5.3
O	0.79	1	1.13	1.43	6.3
P	0.14	1	0.25	1.78	5.0
Q	2.03	1	0.95	0.47	7.1
R	2.10	1	2.88	1.37	3.9
S	6.70	N/A	2.88	0.43	1.5
Shore Drainage	3.21	N/A	N/A	N/A	N/A

1. Area via planimeter on 1:25,000 scale; therefore projected rather than true area.
2. Stream lengths calculated directly from 1:25,000 scale map; therefore projected and not corrected for slope.
3. Calculated on 1:25,000 scale; does not include extension of channels into contour crenulations.
4. N/A - not applicable

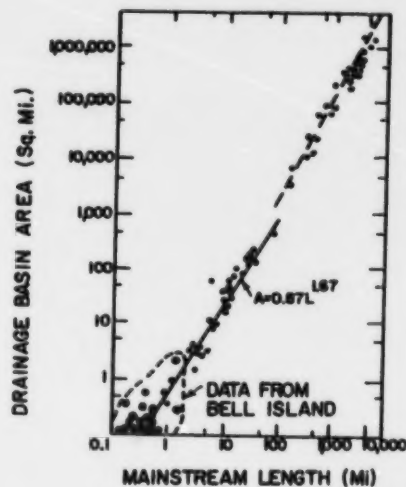


FIGURE B-10 RELATIONSHIP OF DRAINAGE AREA TO MAINSTREAM LENGTH (after Dunne and Leopold, 1978)

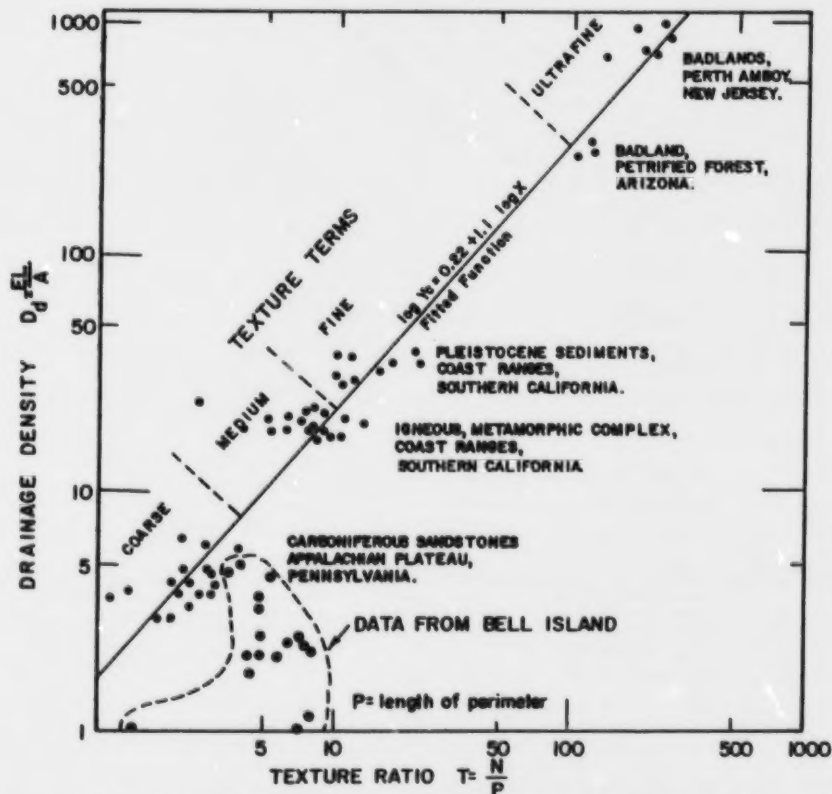


FIGURE B-11 DRAINAGE DENSITY vs. TEXTURE RATIO (after Strahler, 1957)

FIGURE B-10 & FIGURE B-11

- the generally high resistivity of the terrain to erosion due to thin overburden, bedrock, outcrops, vegetation cover and relatively low topographic gradient over the central axis of the island.

The low drainage density explains the relatively low Shreve Stream order numbers for the main channel. However, even with the low numbers, the theoretical ratios of the length of the main channels to drainage area relationship appear to be roughly what theory would predict although there is a lot of scatter (Figure B-10). This density has increased the length of overland flow to the channels, thereby also reducing the sediment delivery ratios and thus the transport of sediment out of the basin.

B-5.2.3 Channel Morphology

Generally speaking, the watersheds exhibit a straight (Sinuosity ratio <1.5), single channel system (with no evidence of lateral migration) for the transport of water and sediment out of the system.

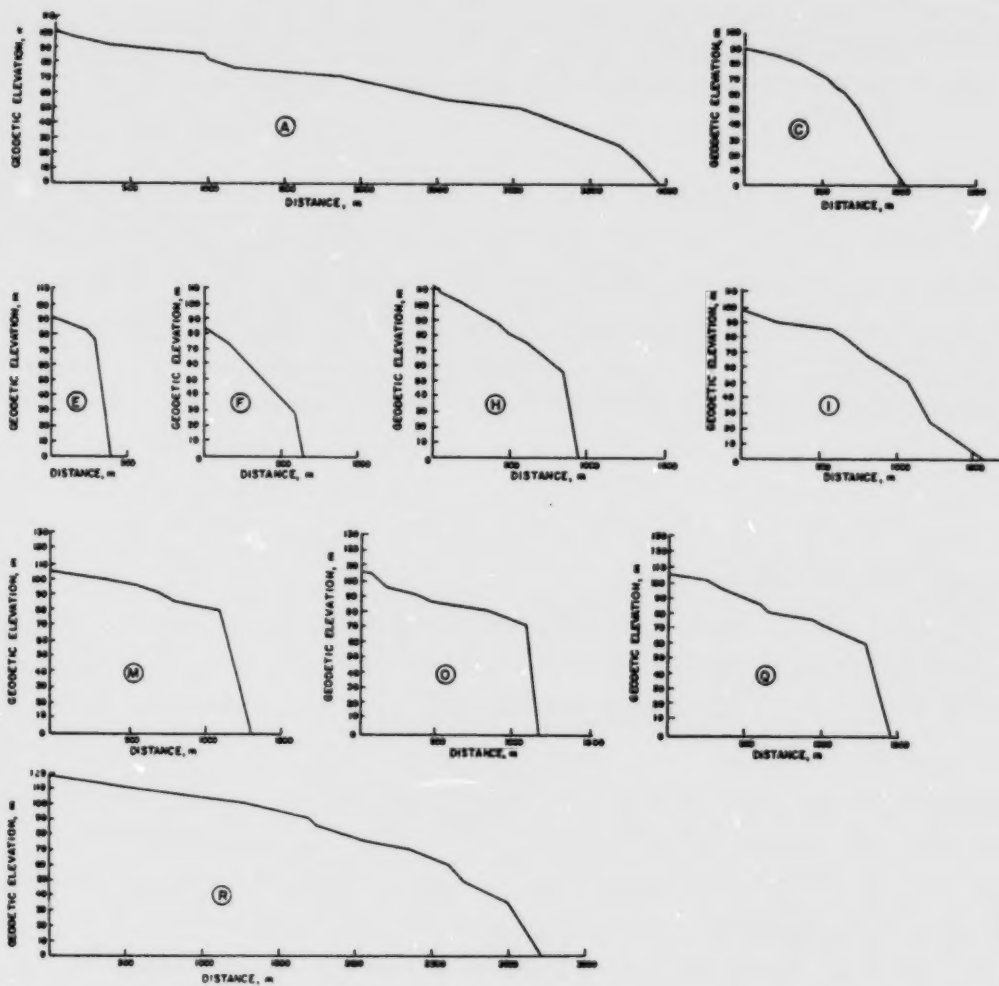
The channels are characterized by high width/depth ratios when traversing areas underlain by glacial till. These reduce significantly when crossing organic terrain.

Due to the relatively low topographic relief over the surface of the island longitudinal channel slopes are low (Figure B-12). In all cases, none of the profiles reveal the normal concave upward profile near the mouths. The most likely reason for this is the relatively rapid submergence which appears greater than the rate of the stream's regime processes to reach an equilibrium profile.

This submergence further serves to explain the absence of meandering channels and recent stream alluvium deposits. Both of these traits are characteristic of the lower reaches of stream profiles where the concave upward trend is found.

B-5.2.4 Water Discharge

At the time of this study no temporary or permanent water discharge monitoring stations have been established on Bell Island.



Ⓐ INDICATES PERTINENT WATERSHED DESIGNATION.

Scale as noted

FIGURE B-12
PERTINENT STREAM PROFILES

An assessment of the hydrometric stations established within the Avalon Peninsula was carried out to select those that would most closely resemble conditions on the Island, based upon bedrock type, basin size, surface storage, topography, natural land use patterns, surficial geology and length of record. The following two watersheds are thought to provide the best approximation:

	Drainage Area	Period of Record
Rocky River at Colinet STN 02ZK001 (natural flow)	285 km ²	1948 - present
Waterford River at Kilbride STN 02ZMO08 (natural flow)	52.7 km ² (locations noted on Figure B-13)	1974 - present

The main problems in extrapolating these data to Bell Island include the larger watershed size, and the draining of higher relief areas with associated variation in climate. The absence of flow records for any streams on the island negates the ability to assess the accuracy of the extrapolation.

The mean annual runoff coefficients are consistent, ranging between 0.040-0.041 m³/s/km² for Rocky River and the Waterford River respectively. This corresponds to 1249 - 1298 mm over the respective drainage basins.

As noted by Gale et al (1984) this mean annual yield is a very large proportion of, or is indeed in excess of, the mean precipitation at nearby precipitation recording station. For example the value of 1298 mm for Waterford River is greater than the total annual normal precipitation at Seal Cove (1277.9 mm) and 86% of that at St. John's Airport (1513.6 mm). It would appear that the precipitation data are not representative of major portions of these drainage basins probably due to microclimatological effects.

Utilizing the historical streamflow data for both stations, runoff coefficients were developed for minimum monthly flows and extreme minimum daily flows.



● INDICATES HYDROMETRIC STATION
▨ INDICATES DRAINAGE BASIN

FIGURE B-13
LOCATION OF PERTINENT HYDROMETRIC STATIONS AND DRAINAGE BASINS

The minimum monthly flows occurring in July within the period of record gave runoff coefficients of 0.017 and 0.014 m³/sec/km² for Rocky and Waterford Rivers respectively. The lower more conservative figure was utilized in subsequent calculations. The extreme minimum daily flows, occurring throughout July and August, ranged over one order-of-magnitude from 0.0007 - 0.007 m³/sec/km² between both stations. These runoff coefficients were then utilized to predict flows within the major watersheds on Bell Island. The data are shown in Table B-6.

Analysis of the flow data by Gale et al (1984) during A) 1981 when precipitation, was within 5% of normal and B) 1977 when precipitation was 10-15% below normal indicated that:

- 1) During 1981 the total volume of water discharged from the Waterford River and Rocky River watersheds was 7.89×10^4 and 7.01×10^5 DAM³, respectively. This formed 92% and 103% respectively of the total precipitation.
- 2) During 1977, the total volume of water discharged from the watersheds was 5.29×10^4 and 2.61×10^5 DAM³ respectively or 68% and 76.5% of the total precipitation.

These two watersheds exhibit a seasonal runoff pattern similar to representative basins on the Avalon Peninsula as shown by Gale et al (1984). Peak runoffs generally occur in April and again in late fall. Low monthly flows are characteristically in the June, July, August period and are in the range of 25-50% of mean annual flows.

There is no evidence of the "Labrador pattern" within the data as noted in some stations within the Trinity Bay area to the west by Nolan, Davis & Associates (1982).

A further discussion is provided in Section B-5.4.

B-5.2.5 Limnology

There are only two natural lakes on the island, namely Bell Pond (watershed O) and Lance Cove Pond (watershed R). In addition, there is one man-made impoundment at the headwaters of Freshwater Brook. In combination they cover only 1.8% (44.62 hectares) of the Island's surface. There is no data available concerning the limnological characteristics of these lakes.

TABLE B-6

Predicted Flows for Major Watersheds
on Bell Island

Watershed	Mean Annual Discharge (m ³ /s)	Minimum Monthly Discharge (m ³ /s)	Extreme Minimum Daily Discharge (m ³ /s)
A	0.229	0.078	.004 - .039
B	0.012	0.004	.0002 - .002
C	0.025	0.009	.0004 - .0044
D	0.023	0.008	.0004 - .0040
E	0.008	0.003	.0001 - .0014
F	0.024	0.008	.0004 - .0041
G	0.031	0.011	.0005 - .0053
H	0.025	0.009	.0004 - .0044
I	0.041	0.014	.0007 - .0072
J	0.018	0.006	.0003 - .0032
K	0.011	0.004	.0002 - .0020
L	0.009	0.003	.0002 - .0015
M	0.038	0.013	.0007 - .0067
N	0.014	0.005	.0002 - .0024
O	0.032	0.011	.0006 - .0055
P	0.006	0.002	.0001 - .0010
Q	0.081	0.028	.0014 - .0142
R	0.084	0.029	.0015 - .0147

B-5.3 Groundwater Hydrology

Assessment of the existing data, indicated the presence of 7 major hydrostratigraphic units (HU) on the Island. It must be cautioned that this definition is developed primarily from geological descriptions of the various units coupled with theoretical values of associated hydrogeological characteristics. There is a major deficiency in field measurement of pertinent hydrogeological parameters for all the units.

The major HU's include:

Bedrock HU's:

- Bell Island HU
- Redmond HU
- Wabana HU

Surficial HU's:

- Till HU
- Soil HU
- Fill HU
- Organic HU

A description of each unit is provided below.

B-5.3.1 Bedrock - Bell Island HU

This unit comprises that portion of the paleostratigraphic Bell Island Group encompassing the Beach and Ochre Cove Formations. It generally underlies the south-eastern half of the island encompassing about 57.9% of the island's surface.

Lithologically, it is principally comprised of massive grey to black shales with relatively numerous persistent interbedded sandstones. The higher frequency of the latter units is the only criteria used to isolate this unit from the Wabana Group.

Discontinuities, primarily joints and bedding planes, are well developed throughout the sandstones. From limited field exposures, they can be described as systematic, open and shear type with a relatively high continuous frequency. They appear persistent and well developed in three dimensions. The spacing between the vertical joint sets is much smaller (narrow to moderate wide 6-200 mm) than the bedding plane openings which are in the range of 200 mm -> 2 M. The joint sets terminate at the over and underlying shales. The aperture of the discontinuities is wider along the bedding planes than for the joints. No staining or evidence of matrix diffusion was noticeable in the exposures examined.

Discontinuities are, however, poorly developed within the shale sequences; being best described as non-systematic, tight and partially closed with iron staining, shear type with a relatively low and sporadic frequency as well as non-persistent (usually <2 m) and poorly developed in three dimensions. The bedding plane fracture is not visually distinctive and more closely resembles a hackly fracturing.

Practical experience elsewhere has indicated the possibility of a more highly fractured zone near the subcrop surface due in part to glacial unloading. This could not be confirmed from the exposures noted.

Faulting is noticeable at a number of locations in this HU along the southeastern shore of the Island.

On a more detailed scale of assessment it is quite likely that each individual sandstone bed may be classified as a separate aquifer or HU. However due to the relatively thin nature of the beds this would require more intense hydrogeological investigation than which is presently possible. Therefore, at this time the unit will be considered "en-masse" except for one thick sandstone unit, namely the Redmond HU.

Theoretical bulk hydraulic conductivity values for such a unit could be in the range of 10^{-5} to 10^{-7} cm/sec.

In general terms, this unit can be best described in bulk terms as a anisotropic, heterogeneous, consolidated, fractured aquifer.

B-5.3.2 Bedrock - Redmond HU

This unit comprises specifically the geologically defined Redmond Formation. It therefore is located within the Bell Island HU. This unit underlies the central portion of the island, encompassing some 17.8% of the total surface area. Lithologically, it is comprised of a massive medium grained sandstone with two thin interbedded shale zones.

From inland field exposures around the reservoir the discontinuities seen are primarily the vertical joint set; due to poor exposure, bedding plane discontinuities could not be isolated. It is expected to be present given Fong & Butler's (1970) notation that the middle set bed is readily recognized by its characteristic behaviour of breaking into tabular flagstones. The discontinuities can best be described as a Systematic, open, shear type with a relatively high

consistent frequency. As they appear to be persistent and well developed in three dimensions. The spacing between the vertical joint sets is narrow to moderately wide 6-200 mm. No staining or evidence of matrix diffusion was noticeable. It was not possible to ascertain the presence of any near surface highly weathered zone.

Bulk hydraulic conductivity values is expected to be in the range of 10^{-2} to 10^{-4} cm/sec.

In general terms, this unit can be best described in bulk terms as a isotropic, homogeneous, consolidated, fractured media with some matrix porosity.

B-5.3.3 Bedrock - Wabana HU

This unit comprises the portion of the paleostratigraphic Wabana Group which is found under the island; including, the following formations: Power Steps, Grebes Nest Point and Gravel Head as well as the three iron ore members. As such it underlies some 24.3% of the island along the northwest shore. Lithologically, it is similar to the Bell Island Group except for more abundant black shales, oolitic beds and reduced sandstone facies.

From field exposures along the shoreline the discontinuities are primarily a hackly type fracturing along bedding planes and fracture cleavage. Vertical joints are very rare and when present are short and discontinuous due to the incompetence of the unit.

Given the variety of sandstone facies, the mining out of the ore bodies and the absence of jointing, it is expected that the unit will result in relatively low bulk hydraulic conductivity values, probably in the range of 10^{-7} - 10^{-10} cm/sec.

In general terms, this unit can probably best be described in bulk terms as a isotropic, homogeneous, consolidated, media exhibiting short discontinuous fracturing along bedding planes.

B-5.3.4 Surficial - Till HU

This unit comprises the basal till deposited over the island by the last glacial advance. Lithologically it can exhibit a variable texture. From limited road side exposures on the island it appears to be a

compact, slightly stony, fine sandy silt to silty very fine sand. No fracturing or development of macropores was visually noticeable.

A bulk K value, based of 10^{-4} to 10^{-7} cm/sec range is expected to represent this unit.

It can best be described "en masse" as anisotropic homogeneous, unconsolidated non-fractured medium.

B-5.3.5 Surficial - Soil HU

This unit comprises the 0.3 - 0.9 m thick soil profile developed over the basal till within the watershed. For the level of accuracy required for this study all soil types will be lumped together since they form part of the Podzol soil group.

Based upon visual examination and literature values, hydraulic conductivities can be expected to be in the range of 10^{-1} to 10^{-3} cm/sec in at least in the A horizon.

B-5.3.6 Surficial - Organic HU

This unit comprises the organic terrain (peat bogs) on the island. Based upon literature values, hydraulic conductivities can be expected to be in the range of 10^{-3} cm/sec.

B-5.3.7 Surficial Fill HU

This unit comprises the man-made fill material and disturbed natural material. Lithologically it can be expected to have a wide variation in grain size, lithology, density, porosity, etc.

It is expected to exhibit an extremely wide range in permeability.

In bulk terms it can be best described as an anisotropic, heterogeneous, unconsolidated, non-fractured, discontinuous medium.

B-5.4 Conceptual Flow Model

Given the scope of this evaluation and limited available data, a conceptual rather than numerical model was utilized for the explanation and prediction of water movement within the hydrologic cycle.

B-5.4.1 Generation of Flow

B-5.4.1.1 Surface Water

Some 88% of the Island is wooded or rural. Therefore, given the humid climate, predominance of natural vegetation growth, low topographic relief, wide valley floors, and .3 - .6 m deep Soil HU, the variable source model of forest zone hydrology is applicable rather than the Horton overland flow model in describing the factors governing storm runoff and stream flow. This model would not be expected to apply over the Redmond HU were a ground water table model may be more appropriate.

The Horton overland flow model is expected to be more applicable in the roughly 12% of the area covered by urban - Suburban land use, principally found in Watershed S. Each of these models is discussed further below.

Pertinent points of the variable source model include the following:

- A) Infiltration capacities are high because vegetation protects the soil from rain-packing and dispersal and because the supply of humus, the activity of microfauna and frost action create an open soil structure. Under such conditions rainfall intensities are less than infiltration capacity and overland flow does not occur.
- B) After infiltration occurs, the deeper flow movement follows the conceptual model developed for groundwater flow in Section B-5.4.1.2. During storm events the main groundwater flow is probably shallow subsurface storm flow or "interflow" which is perched over the Till HU. When interflow is the dominant contributor of storm runoff, the volume of storm flow reaches the channel only slowly and does not attain the same peak discharge rates as those generated by Horton overland flow. As well, hydrograph peaks lag considerably behind rainfall with much flatter recession limbs. Larger volumes of interflow can be expected to move over the 39% of the island which has been cleared but not grubbed, due to lower evapotranspiration losses.

- C) In the wide shallow valleys, characteristic of the island, the water table is closer to the surface than under the topographic highs. This and the shallower depth of the water table ensures that vertical percolation will cause the water table to rise quickly in the valleys near the streams early in a storm. If the rainstorm is large enough or the water table or impeding horizon shallow enough, infiltration will cause the water table to rise to the ground surface allowing water to escape from the soil and flow to the channel over the land surface via overland or return flow.

That portion of the hillside over which return flow emerges from the surface is impervious to rain falling on it. This rain runoff together with return flow will be called saturation overland flow in the remainder of the report. It moves with velocities order-of-magnitude faster than those of subsurface storm flow and can supply runoff to the channel more quickly (Dunne & Leopold, 1978). The peak rates of channel discharge however are less than those for Horton overland flow because only a portion of the drainage basin is contributing flow.

As the storm progresses, the saturated area expands upslope, causing more of the catchment to contribute saturation overland flow. This saturated area also expands and contracts seasonally.

- D) Visual inspection of channel form indicates that most channels within the watershed exhibit large width/depth ratios. This is controlled by channel downcutting through the soil profile and slightly into the till. Deep incision into the till is restricted however by development of a lag pavement or bedrock outcrop. Therefore the main hydrostratigraphic unit of high permeability controlling flow into the channel is the Soil HU.

- E) During non-storm events stream flow is controlled immediately after the storm event by the processes described above. At some point later in the recession the more regional groundwater flow patterns in the till and bedrock become dominant as does control from large surface water storage units created by lakes, and organic terrain.

A water table model would be more appropriate in describing the area overlying the Redmond Formation due to the very thin and mostly discontinuous till cover. The absence of this relatively low permeable cover would allow precipitation to infiltrate quickly through to the Bedrock aquifer, which could be expected to be under water table conditions at its outcrop.

The Horton Overland Flow model is applicable to the urbanized areas due to the absence of vegetation and reduced permeability of the ground surface.

B-5.4.1.2 Groundwater

The groundwater model relies on two systems: the Hydrogeologic Environment and the Groundwater Regime. What is known about the "regime" parameters has been outlined in Section B-5.3. The physical conditions resulting from the combination of topography, geology and climate constitute the "hydrogeologic environment". Given the cause-effect type relationship which exists between the environment and the groundwater regime, the evaluation of certain properties of the latter are possible if the former is known. These three critical parameters have been discussed separately (Sections B-3 and B-4). The inferences that can be drawn concerning the groundwater regime from these three parameters are discussed below.

Climate Controls

- A) Water balance calculations are shown diagrammatically on Figure B-14. Unfortunately, no valid hydrographs of water table/piezometric surface fluctuations are available for inclusion in this diagram. Pertinent points are outlined below:

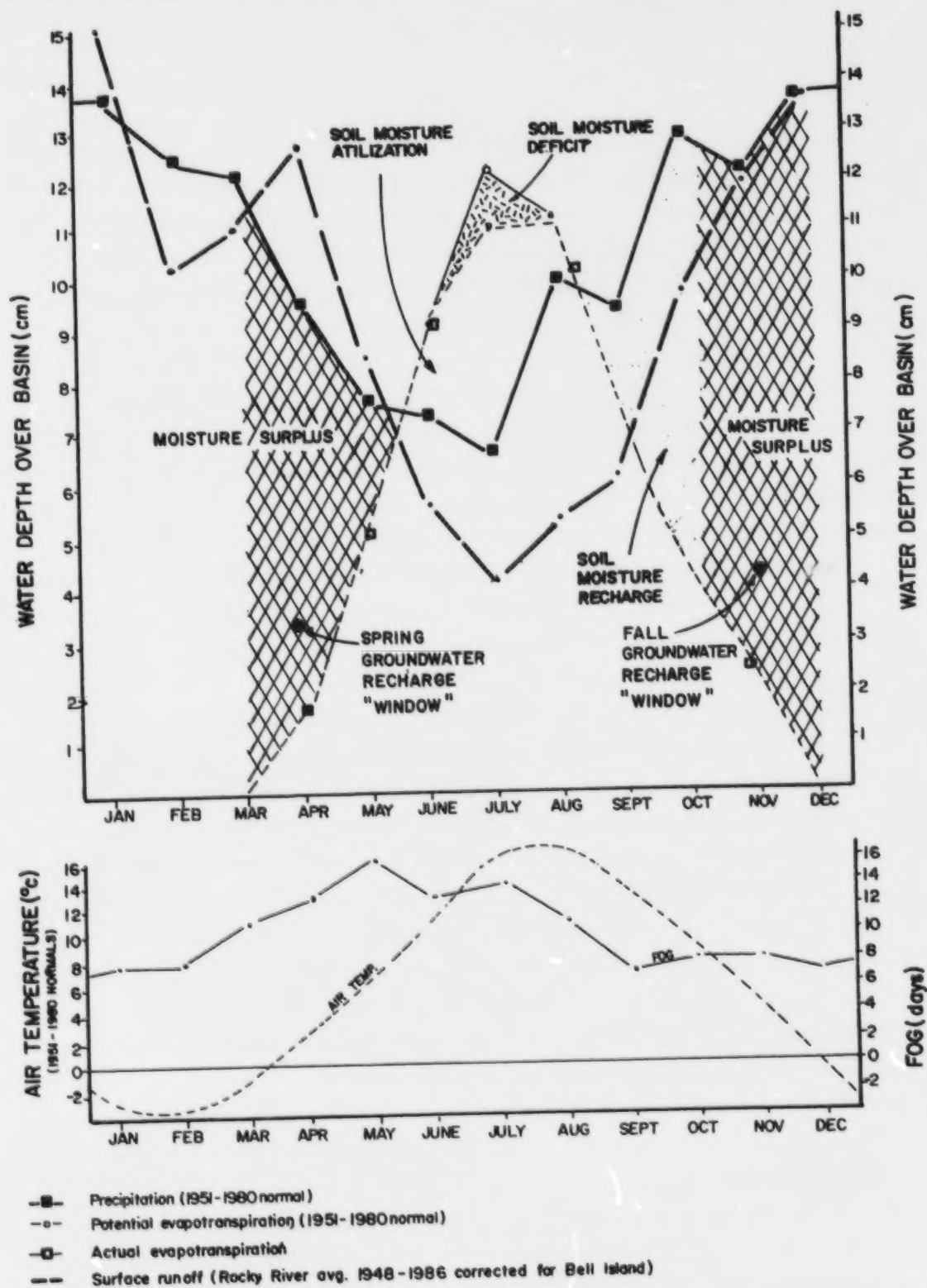


FIGURE B-14
WATER BALANCE DIAGRAM
BELL ISLAND

- I The study area receives a relatively large volume of precipitation (1272.9 mm), with relatively low evapotranspiration. This results in a low annual moisture deficit of 15 mm and a large annual surplus of 608 mm. The evapotranspiration loss should be considered as maximum since it does not account for humidity which peaks as fog/mist slightly in advance of peak air temperatures.
- II The annual surplus is distributed over eight (8) months in two distinct wet seasons, winter-early spring (January to May inclusive) and late fall (October-December) inclusive.
- III During the initial portion of the winter-spring wet season, air temperatures are below freezing. The moisture surplus goes into storage as snow, and although there are numerous snow melts during winter, the development of frost probably restricts recharge of the bedrock aquifer. As a result, this snowmelt is lost to stream flow. Warming trends primarily in April, release the snowpack storage and eliminate frost cover allowing for a major groundwater recharge "window". The volume of water released at this time is however probably greater than the infiltration rate and a large portion is lost to stream flow; so much so that streamflow is greater than precipitation received in the respective months.
- IV During October - December, precipitation occurs mostly as rain due to the high air temperatures. The absence of frost allows this to form the second major recharge window.
- V During the summer months, evapotranspiration rates exceed precipitation, peaking in July. The result is the recession curve seen in streamflow. The deficits in soil moisture incurred in June, July and August are quickly replenished in September. During this replenishment the recession curves bottom out.
- B) Given the large water surplus, water tables/piezometric surfaces are expected to be quite high; thereby resembling the surface topography. This results in a maximum of possible fluid potential differences within the groundwater flow field.

- C) Generally the greatest volume of infiltration and recharge to the deeper groundwater hydrostratigraphic units is associated with long duration, low intensity type rainfall. It is specifically this type of rainfall which characterizes the study area. Therefore recharge should be enhanced; all other things being equal.
- D) The mean annual air temperature of 6.1°C creates groundwater temperatures in the 5-10°C range as noted from Department of Environment records at North Pond Brook, Torbay.

Geologic Controls

- A) Given the low permeability of the Till HU, a portion of recharging precipitation is perched moving as interflow through the Soil HU and down topographic gradient. This process is further heightened by development of impermeable "pans" in the lower B horizons of the Soil HU. Although this movement is technically part of the groundwater flow system, it has been referred to as a component of the surface water flow field for this report.
- B) The deeper groundwater flow system is believed to be controlled by the relatively highly permeable sandstone facies set within a matrix of relatively low permeable shales/siltstones.

Recharge to these sandstones aquifers would occur both at the subcrop surface where water table conditions, would exist, if no confining layer is present, as well as vertical leakage out of the aquitards.

The northwest dip and northeast strike will likely result in groundwater flow within these units directed toward and discharging primarily to the sea where they outcrop at the shore at the northeast and southwest sectors of the Island. Secondary discharge points are bedrock outcrops in stream channels, as well as vertical flow up into the confining beds after artesian conditions are created at depth. It is presently expected that minor flow volumes would be directed toward and discharge along the southeast shore of the island.

If this conceptual model is correct, then groundwater flow systems within the bedrock will not resemble surface water watersheds. This may allow for interbasin transfer of groundwaters along bedrock strike.

Although the ore zones are recorded as being heavily fractured and therefore permeable, they have for largely been mined out. They are, therefore, not expected to be pertinent to this discussion.

- C) The annual rate of groundwater recharge on the island was calculated using a range of data. Brown (1967) assumed that groundwater is recharged at a rate of ~15 cm (12% of Bell Island's total annual precipitation) per year in Atlantic Canada. Other authors in more recent studies have estimated recharge at substantially different values. In Nova Scotia calculated values over sedimentary bedrock terrain gave ranges of 13-23% of total precipitation (Gibb et al 1980; Vaughn et al 1980). Gale et al (1984) calculated 25-32% for the two water discharge stations used for this study. Applying this range of data to Bell Island results in the following volume of annual recharge:

10% of total annual precipitation	3503 DAM ³
20% of total annual precipitation	7006 DAM ³
25% of total annual precipitation	8768 DAM ³
32% of total annual precipitation	11,210 DAM ³

It should be noted that in the references cited, all except Brown, utilized streamflow separation techniques to arrive at the recharge rate. This technique however assumes that all infiltration will appear in streamflow. This does not account for "underflow" losses through discharge out of the basin primarily through the bedrock HU's. Given the high bedrock cliffs around the island this may be of significance for Bell Island. These results should therefore be regarded as conservative.

The distribution of this volume between the shallow and deep groundwater flow systems is unknown.

- D) Piezometric surfaces within the bedrock are assumed to be subdued under topographic highs if the more permeable sandstone units are present. In the lowlands, or in the uplands where rock types are more argillaceous and permeabilities are reduced, the piezometric surface may be high enough to coincide with perched water tables at the rock/till or soil profile interface.
- E) Infiltration of precipitation is facilitated by low slopes. Therefore groundwater recharge should be increased by the generally low slopes that are prevalent over the island's surface.
- F) The rising sea levels have and are reducing the size of the study area by shoreline erosion. As such the flow fields are relatively short. No data is available on the rate of erosion but the visual appearance suggests it is far in excess of the sea level rise of 0.3 m/century. Therefore, groundwater flow gradients in the bedrock aquifer may be increasing substantially, contemporaneous with an increasing extent of salt water intrusion.

B-5.4.2 Routing of Flow

Once storm or non-storm flow has been "generated," the routing of flow i.e. travel time, volumes, etc. are more a function of drainage basin and channel morphological characteristics. Given the low drainage densities and texture ratios of the watersheds the length of time for generated flow to reach streams is relatively long. Once flow has entered a water-course the relatively straight configuration ensures the minimum travel time possible, given the low longitudinal slope.

B-5.5 Resource Calculations

The calculation of the volume of fresh water on the island is broken down as follows:

- 1) "Replenishable Resource" i.e. that volume recharging the cycle each year from rainfall and
- 2) "Non-Replenishable Resource" i.e. that volume held in storage.

Given the limited data available, calculations should be regarded only as order-of-magnitude estimates. Further, they do not imply the volume of water capable of being extracted i.e. safe yield of the system.

B-5.5.1 Replenishable Resources

Some 35,030 cubic dekameters (DAM^3) of water fall on the island in a "normal" year ($1 \text{ DAM}^3 = 1000 \text{ m}^3$).

Assuming the actual evapotranspiration rate of 516 mm/year applies to the entire island there is a loss of 14,200 DAM^3 of water per year through evapotranspiration. This leaves the annual replenishable water resource on the island at 20,830 DAM^3 .

Utilizing Gales (1984) data, some 8700 - 11,200 DAM^3 (42-54% of the replenishable resource goes into the groundwater flow field and 46-58% is directed toward the surface water flow field annually).

B-5.5.2 Non-Replenishable Resource (Storage)

The calculation of groundwater storage assumes that it occurs primarily within the bedrock hydrostratigraphic units. This assumption was made because of the expected small saturated thickness of the surficial material.

The lower boundary of the bedrock hydrostratigraphic unit has been assumed to be 91 metres. This assumes no salt water intrusion above this depth.

The following calculations do not take bedrock fracturing into account; therefore, they should be considered to be conservative.

Assuming that shales and siltstones underlie approximately 90% of the Island, the total groundwater storage volume in the siltstones and shales probably range from 0 to $2.3 \times 10^5 \text{ DAM}^3$. Assuming that the remainder of the Island is underlain by sandstone, the total groundwater storage volume in this material can be expected to range from 1.3×10^4 to $7.5 \times 10^4 \text{ DAM}^3$. The overall volume of potential groundwater storage in the upper 91 metres of the island is therefore likely in the range of 1.3×10^4 to $3.1 \times 10^5 \text{ DAM}^3$.

The main surface water reservoir on Bell Island contains approximately 75.7 DAM³. The volume stored in stream channels is approximately 6.9 DAM³. Therefore, the total volume of surface water in storage on the Island is in the order of 82.6 DAM³.

Overall, there is conservatively 10,000 DAM³ of fresh water in storage in both surface and groundwater on Bell Island. However, this may range up to 300,000 DAM³.

B-6.0 THE GEOCHEMICAL CYCLE

B-6.1 Definition

The geochemical cycle (Figure B-15) defines the movement of elements, minerals and/or compounds; whether they be dissolved in the water column or absorbed onto sediment particles. As such, the major factors controlling their movement have already been defined by the hydrologic cycle. The Debris Cycle also controls some of the movement but is not considered here. For this report, these constituents will be defined as "particles" <0.45 microns in size.

Essentially, the cycle can be broken down into the assessment of the cycling of the elements through the biosphere, lithosphere, hydrosphere and atmosphere. Given the terms of reference, the biosphere will not be included within this discussion.

Due to the limited data available and the practical nature of this investigation, it was decided not to assess the geochemical cycle on the bases of individual elements i.e. the carbon or nitrogen cycles. Instead, the following discussion is divided into two areas:

- 1) The "geochemical" landscape - The net effect of all the dynamic forces concerned in the movement of earth materials is reflected in the overall distribution of the elements throughout the landscape.
- 2) Element Mobility - The factors controlling the movement of the elements between different sections of the geochemical landscape is determined by their mobility.

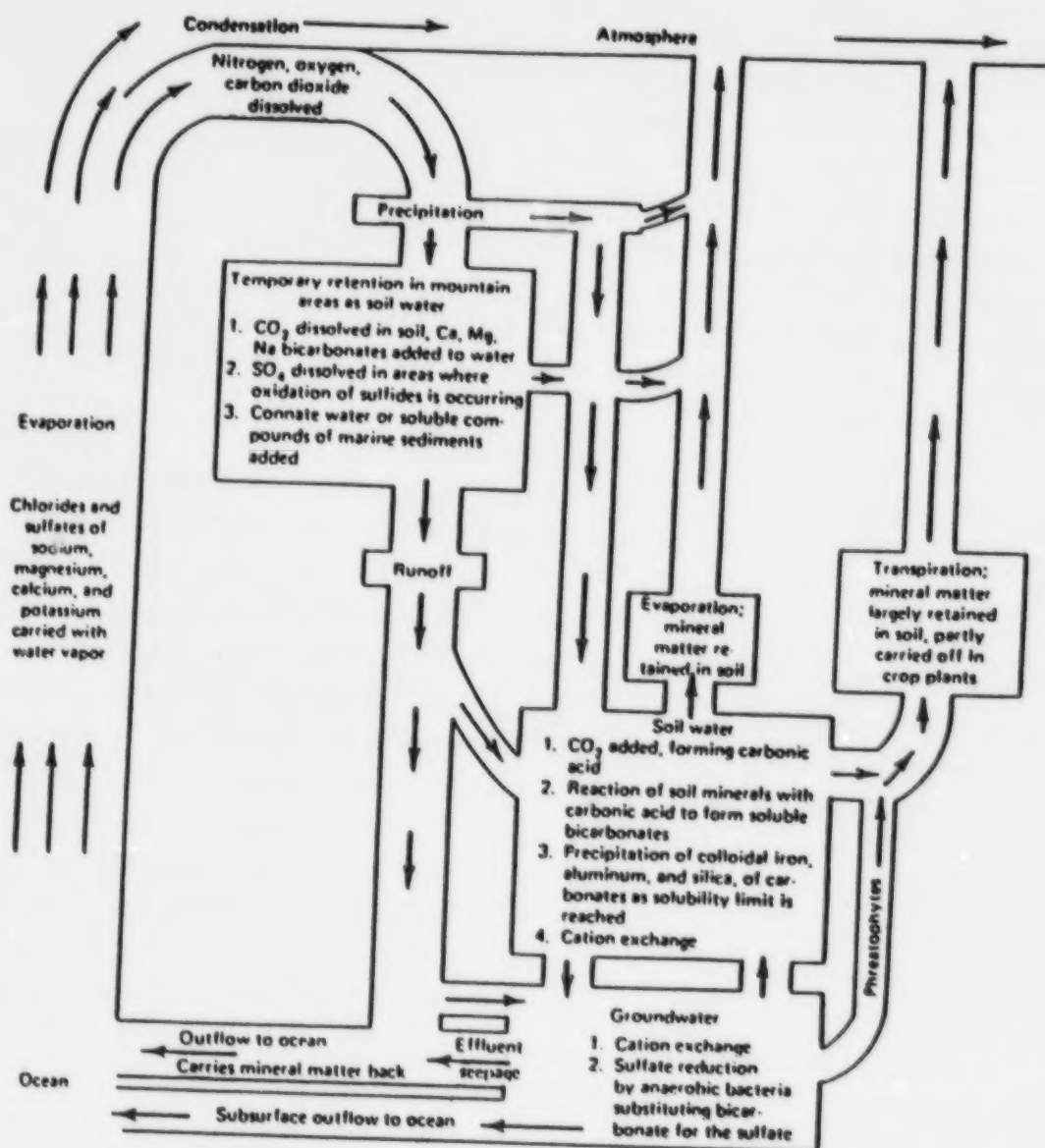


FIGURE B-15
DIAGRAMATIC REPRESENTATION OF THE GEOCHEMICAL CYCLE

B-6.2 Geochemical Landscape

No data is presently available on the primary and secondary syngenetic and epigenetic dispersion patterns found within the geological units on the island, except the bedrock. Limited work has been carried out to investigate the detrital and non-detrital (i.e. total) concentrations of certain elements within the various bedrock units especially the iron ore bodies.

The origin and nature of the Clinton type oolitic Iron Ore Formation at Wabana, as described by Hayes (1915) and Gross G.A. (1967), is summarized below:

- . The iron ore occurs as a primary bedded deposit.
- . The source of the iron in the beds cannot be established with any degree of certainty. Hayes has inferred that the iron was derived by long continued weathering of earlier rocks, taken into solution and transported to the sea as inorganic and organic acid compounds.
- . In general, the spherules of the ore vary in size from 0.1 to 0.5 mm and are composed of alternating concentric layers of hematite and chamosite precipitated out near the surface of deposition. Siderite occurs in smaller quantity but becomes locally abundant.
- . Siderite has replaced both chamosite and hematite and in many instances detrital quartz as well while the sediments were still unconsolidated. The only secondary minerals to the iron are calcite and quartz.
- . There is a total lack of limestone from the series. Practically all of the original calcium content of the ore, averaging ~ 2.5% is present in the form of fossil remains composed largely of calcium phosphate.
- . Oolitic pyrite also occurs frequently alternating with layers of phosphatic material.

The whole rock analysis given by Hayes to support these statements are summarized in Table B-7. Pertinent points include:

- 1) Analyses A-B are taken from a sandy shale and sandstone respectively within the Bell Island HU. Both show considerable iron and alumina but no lime. Since the ore is essentially a primary sediment and its constituent materials were brought together in the first instance by

TABLE B-7

WHOLE ROCK ANALYSES (AFTER HAYES 1915)
OF ORE AND NON-ORE ZONES

	A	B	C	D	M	N
			in percent			
SiO ₂	57.00	76.50	11.98	12.59	8.39	12.66
Al ₂ O ₃	15.98	6.05	5.13	5.71		
TiO ₂				0.27		
P ₂ O ₅			2.02	1.63		3.24
Fe ₂ O ₃	8.83	2.14	75.90	75.12	78.38	48.60
S			0.03	0.00		
CaO	0.00	0.00	2.71	1.49		
MgO			0.21	0.42		
MnO			0.23	0.06		
CO ₂						
H ₂ O-				0.52		18.17
H ₂ O+			1.86			
Loss on ignition				2.17		
TOTAL			100.07	99.98		
Sp.Gr.				4.10		4.40

Description

- N - Ore from upper part zone 2, Dominion bed, holding siderite, surface outcrop.
M - Ore from zone 2, submarine workings.
D - Average sample ore from zone 2, Dominion bed.
C - Average sample ore from zone 2, Dominion bed.
B - Sandstone halfway across Bell Island.
A - Sandy shale from halfway up cliff at N.S.S. and C.Co. pier.

Table of Analyses

	E	F	G	H	I	J	K	L
			in percent					
SiO ₂	36.61	14.80	49.21	18.80	17.64	46.90	16.99	34.48
P ₂ O ₅	0.08	2.29	0.48	0.94	1.11	0.20	1.25	0.11
Fe ₂ O ₃	33.18	73.04	27.83	71.88	68.26	32.46	45.94	37.68
S	0.15	0.03	0.25	0.02	0.005	0.63	0.39	0.01
CaO	0.00	3.24	0.64	1.12	1.16	1.38	1.76	0.18

Description

- L - Shales above zone 2 ore, surface outcrop
K - Oolitic hematite and chamosite ore, zone 2, surface outcrop
J - Oolitic hematite ore containing much quartz. Zone 2, surface outcrop.
I - Oolitic hematite ore containing phosphatic pebbles and shell fragments. Zone 2, surface outcrop.
H - Oolitic hematite ore, zone 2, surface outcrop.
G - Parting rock of fine-grained ferruginous sandstone. Zone 2, surface outcrop.
F - Oolitic hematite and chamosite ore.
E - Fine-grained sandy shale on floor of workable bed. Zone 2, surface outcrop.

mechanical means a heterogeneous mixture has resulted and an exact mineralogical composition is difficult.

- 2) Analyses C and D are nearly complete and were made from average samples of iron from the Dominion Bed ore seam. Those in combination with two samples of the Scotia ore seam are noted below:

		Dominion	Scotia
Hematite		65.51%	50.08-67%
Chamosite			
	SiO ₂	6.00%	
	Al ₂ O ₃	5.42%	
	FeO	9.99%	23.89%
	MgO	0.32%	17.65-18.0%
	Mn	0.15%	
	H ₂ O+	2.01%	
Calcium phosphate (CaO) ₃ P ₂ O ₅ in form of shell fragments		4.43%	4.46-4.6%
Quartz		5.98%	
Hygroscopic Water		0.52%	0.37-0.32%
Siderite			2.77-27.6%
Calcite			0-0.68%
Vivianite			0-0.83%

- 3) Analyses E, F, G, H, I, J, K, L were made from a series of samples taken at intervals from bottom to top, of the Dominion Bed. The small amount of sulphur shown by these analyses probably occurs in the form of iron sulphide.

B-6.3 Element Mobility

As the input precipitation waters move through the geotechnical "landscape," their chemistry changes significantly; thereby effecting their mobility.

The "landscape" has therefore been divided up onto sectors as defined by precipitation, the main hydrostratigraphic units and surface channels for the following discussion. Unfortunately, very little data is available for this discussion. Essentially, only three have been assessed; including:

1. precipitation chemistry at ground surface
2. surface water chemistry at the point of discharge from a basin
3. the bedrock HU's

Of these areas, 1 and 2 incorporate extrapolations from data collected elsewhere. This lack of data restricts the discussion to that of outputs from each sector; nothing can be stated regarding the processes a work within each sector. It was necessary, therefore, that the "black box" approach be used.

B-6.3.1 Precipitation Chemistry

At the present time, both the Federal and Provincial governments have implemented programs to monitor the chemistry of rainfall at various locations in Newfoundland.

The nearest station to the study area exhibiting long term continuity is located at Bay D'Espoir, a federal government CAPMON station. It commenced readings in November 1981 as part of the Air Precipitation Network. It is located some 290 km west-southwest and therefore slightly upwind of Bell Island along the southern shore of Newfoundland. The station analyzes wet fallout on a storm event sampling basis. A partial chemical analysis (11 parameters) is completed on each sample.

Due to the prevailing westerly winds, Newfoundland lies within the airshed of many densely populated, highly industrial areas in the eastern U.S. Seaboard and the St. Lawrence Valley - Great Lakes region of Canada and the U.S. This coupled with the long atmospheric residence times of SO_2 and NO_x compounds places the province in a position conducive to the receipt of potential acids and other contaminants from "long range" transport. Further the province lies at the downwind sector of the Maritime provinces placing it therefore in partial receipt of "intermediate" range provincial emissions.

The positioning of this station allows it to characterize primarily the influence of long and intermediate range anthropogenic emissions on "natural" precipitation chemistry. However, Bell Island is some 25 km north-northeast and therefore immediately downwind of a major short range anthropogenic emission source namely the 450 megawatt oil fired thermal generating station at Holyrood. Pertinent data for this plant indicates SO_2 emissions for the 1983-1987 period inclusive of 7,600, 9,600, 19,300, 15,500 and 23,000 tonnes respectively. These figures represent 21, 26, 38, 36 and 46% respectively of the total provincial SO_2 emissions. The increasing emission rates is due primarily to lack of water at hydroelectric plants and increased demand.

It is, therefore, expected that acid rainfall conditions may be more pronounced on Bell Island than the Bay D'Espoir data suggests.

An analysis of the available data sets for the Bay D'Espoir Station (1984, 1985 and 1986 calendar years) indicated the following pertinent points (raw data is provided in Appendix B).

- . A summary of the pertinent data is presented in Table B-8.
- . The data indicates that precipitation on an annual average basis can be characterized as a fresh (partial ion sum 3-5 mg/l), soft probably corrosive, characteristically mixed $\text{Na} - \text{HCO}_3/\text{SO}_4/\text{Cl}$ type water with a pH range of 4.7 - 5.2. The existing format of the data summary does not allow for the definition of seasonal trends.
- . In terms of annual loading rates, chloride and sulfate exhibit the highest rates (10 - 20 kg/ha) over the three years studied. No data is available for alkalinity. Sodium is the third highest at 5.5 - 6.5 kg/ha.
- . The pH range is less than the "normal" 5.7 units attributable to rainfall unaffected by anthropogenic inputs. Therefore, even on a regional basis significant acid inputs are occurring due to regional and/intermediate range transport. Annual loading rates of hydrogen ions fluctuate considerably, covering a range of 18.0 - 29.8 meq/m²/yr. This is similar to "background" data gathered by the Nova Scotia Department of Environment in the northeast sector of Nova Scotia (the landmass immediately upwind). That data indicated a range of 18 - 28 meq/m²/yr for the period 1982-1984 inclusive (Underwood, pers. comm.). These figures corresponded with the northeastward decline across Nova Scotia from 30-40 meq/m²/yr in the southwest.
- . Excess SO_4 annual loading rates were calculated to range from 20.0-27.2 meq/m²/yr. These figures are significantly lower than the background values obtained in Cape Breton at 34.7 - 47.1 meq/m²/yr (Underwood, 1981) or in the industrial Sydney area of 70 meq/m²/yr (Baechler, 1986). This continues the gradient of declining concentrations from around 50 meq/m²/yr in the southwest part of Nova Scotia.

TABLE B-8
Precipitation Chemistry Summary
Bay D'Espoir
1984, 1985, 1986
(Courtesy of Environment Canada)

Parameter	1984		1985		1986	
	mg/l	kg/ha ²	mg/l	kg/ha	mg/l	kg/ha
Na	1.11	N/C	0.90	6.16	0.58	5.98
K	0.11	1.32	0.07	0.55	0.05	0.44
Ca	0.32	4.30	0.10	0.82	0.06	0.44
Mg	0.10	1.32	0.10	0.68	0.07	0.73
Alkalinity (as Ca CO ₃)	1.54	N/C	0.83	N/C		
SO ₄	1.40	15.53	1.37	11.51	1.32	11.08
Cl	1.34	18.18	1.51	10.96	1.00	10.60
NO ₃ as N	0.11	1.16	0.16	1.23	0.19	1.31
NH ₄ as N	0.087	N/C	0.12	0.969	0.083	0.729
pH	5.20		4.88		4.71	
H ⁺		0.1814		0.2863		0.3009
Total Precipitation Days	166		175		194	
Total Precipitation	1658.6 mm		1370.0		1458.0 mm	

1. arithmetic mean over calendar year

N/C not calculated

2. deposition note in kilograms/hectare using precipitation - weighted mean concentration.

- Nitrate (as N) annual loading rates were calculated to range from 8.3 - 9.4 meq/m²/yr. These figures are similar to background data on Cape Breton at 7.41 - 12.9 meq/m²/yr (Underwood, 1981) but are significantly less than those found in the industrial core area of Sydney of 29 - 70 meq/m²/yr (Baechler, 1986).

B-6.3.2 Surface Water Chemistry

No valid surface water chemistry sample analyses could be located for streams in Bell Island.

The station in closest proximity which provides what is considered to be representative data indicated a Naquasat water chemistry sampling station operated by Environment Canada at the Rocky River (Colinet) station utilized in determining discharges in Section B-5.2.4. Spot samples have been collected from December, 1981, to August, 1986, encompassing 64 samples. A statistical summary of the data is presented in Table B-9. It is assumed that the analyses represent filtered aliquots.

The data indicates that surface water can be characterized as a fresh (ion sum 10 - 50 mg/l), soft, corrosive, slightly to highly coloured (15 - 200 TCU), non-turbid, Na-Cl type water with a slightly acid pH range of 5.3 - 6.7. The colour appears to be associated with fluctuating concentrations of dissolved organic carbon (3.7 - 24.0 mg/l). The low milliequivalents of alkalinity averaging 0.02 meq/l, suggests the water is "highly sensitive" to acidification. Of note is the minimal variation in concentrations with the exception of chloride, DOC and pH. The coloured water systems are not always persistent on Bell Island from quick spot checks. Freshwater Brook does not appear to be a highly coloured system.

B-6.3.3 Groundwater Chemistry

Unfortunately, very little data is available on groundwater chemistry on the island. All of the 14 analyses found, were only partial analyses and did not include all of the major ions. What can be summarized from this limited data set (presented table B-10) is discussed below (Note it is assumed that all analyses were carried out on filtered aliquots).

TABLE B-9
Surface Water Chemistry Summary
Rocky River at Colinet
Dec. 1981-Aug. 1986

(Courtesy of Environment Canada)

LOCATION/PROJECT PARAMETERS IN MGL (CDWS)	DEPTH DATE	Maximum Concentration	Minimum Concentration	Mean Concentration	Median Concentration	No Samples		
	TIME							
SODIUM (*)		9.30	2.30	4.814	4.60	64.0		
POTASSIUM (*)		0.506	0.100	0.244	0.244	64.0		
CALCIUM (*)		3.0	0.70	1.630	1.60	63.0		
MAGNESIUM (150)		1.8	0.45	0.858	0.80	64.0		
HARDNESS (AS CaCO ₃) (*)								
ALKALINITY (AS CaCO ₃) (*)		5.80	0.50	3.396	3.50	47.0		
SULPHATE (500)		4.80	1.50	2.854	2.80	64.0		
CHLORIDE (250)		21.6	3.7	8.037	7.10	60.0		
FLUORIDE (1.5)								
SILICA REACTIVE (*)								
TOTAL PHOSPHORUS		0.029	0.001	0.007	0.006	49.0		
PHOSPHATE ORTHO (0.2)								
TOTAL PHOSPHATE								
TOTAL NITROGEN		0.280	0.050	0.120	0.10	62.0		
NITRATE & NITRITE (AS N) (10.0)		0.040	0.010	0.012	0.010	62.0		
KJEL NITROGEN								
AMMONIA (AS N) (0.5)								
SURFACTANTS								
TOTAL ORGANIC CARBON (*)		24.0	3.7	7.770	7.0	60.0		
CHEMICAL OXYGEN DEMAND								
HUMIC ACIDS								
HYDROCARBONS								
PHENOLS (0.002)								
TOTAL DISSOLVED SOLIDS (500)								
SUSPENDED SOLIDS (*)								
COLOR (15 TCU)		200.0	15.0	56.825	50.0	63.0		
TURBIDITY (5 JTU)		1.8	0.3	0.617	0.60	64.0		
CONDUCTIVITY UMHO/CM (*)		87.00	25.0	42.859	41.0	64.0		
FIELD TEMPERATURE (5°C)								
FIELD PH (UNITS) (6.5 - 8.5)								
LAB PH (UNITS)		6.7	5.3	6.217	6.20	64.0		
ALUMINUM (*)		0.770	0.020	0.094	0.078	65.0		
ANTIMONY (*)								
ARSENIC (0.5)								
BORON (5.0)								
BARIUM (1.0)								
BERYLLIUM (*)								
CADMIUM (0.005)		0.002	0.001	0.001	0.001	65.0		
CHROMIUM (0.05)								
COBALT (*)								
COPPER (1.0)		0.015	0.002	0.002	0.002	65.0		
CYANIDE (0.2)								
IRON (0.3)		0.710	0.110	0.253	0.230	64.0		
MANGANESE (0.05)								
MERCURY (0.001)								
NICKEL (*)								
LEAD (0.05)		0.003	0.002	0.002	0.002	65.0		
SELENIUM (0.01)								
SILVER (0.05)								
STRONTIUM (10 Bg/L)								
TIN (*)								
URANIUM (0.02)								
VANADIUM (*)								
ZINC (5.0)		0.090	0.002	0.010	0.010	65.0		
COLIFORM (10/100 ML)								
FECAL COLIFORM (0)								
*NO RECOMMENDED LIMIT								

TABLE B-10
Groundwater Chemistry

LOCATION/PROJECT HU DEPTH DATE TIME PARAMETERS IN MGL (CDWS)	Woods A Well Bell Island Dec. 1976	St. Edwards Well Bell Island Dec. 1976	Bridal Ave. Well Bell Island Dec. 1976	St. Edward School Bell Island June 1984	B. Bennett Bell Island Nov. 1980	Lance Cv. Well Bell Island Oct. 1987	Davidson Ave. well Redmond Dec. 1976
SODIUM (*)				110.0	23.85	37	
POTASSIUM (*)				1.5		1.74	
CALCIUM (*)	33.58	13.89	55.68	7.6	30.48	24	51.90
MAGNESIUM (150)	6.55	1.63	5.561	0.66	7.39	8.7	6.28
HARDNESS (as CaCO ₃) (*)	111.13	91.66	163.16	21.70	129.21	75.2	156.46
ALKALINITY (as CaCO ₃) (*)	121.8	141.0	118.4	179.0	100	11.6	146.2
SULPHATE (500)					22	8.0	
CHLORIDE (250)					43	31	
FLUORIDE (1.5)						0.16	
SILICA REACTIVE (*)							
TOTAL PHOSPHORUS	0.079	0.108	0.062		0.020	0.118	0.071
PHOSPHATE ORTHO (0.2)							
TOTAL PHOSPHATE							
TOTAL NITROGEN							
NITRATE & NITRITE (as N) (10.0)	0.026	0.021	0.120	0.050	0.300	0.015	0.056
KJEL NITROGEN	0.331	0.490	0.101				0.440
AMMONIA (as N) (0.5)							
SURFACTANTS							
TOTAL ORGANIC CARBON (*)							
CHEMICAL OXYGEN DEMAND	< 0.2	< 0.2			9		0.46
HUMIC ACIDS							
HYDROCARBONS							
PHENOLS (0.002)							
TOTAL DISSOLVED SOLIDS (500)				300.0	203	192	
SUSPENDED SOLIDS (*)							
COLOR (15 TCU)				15.0		5	
TURBIDITY (5 JTU)	0.40	0.40	0.10	2.6	.76		1.15
CONDUCTIVITY UMHO/CM (*)	398.87	413.07	458.53	500	320		373.43
FIELD TEMPERATURE (5°C)							
FIELD PH (UNITS) (6.5 - 8.5)							
LAB PH (UNITS)	8.42	8.86	7.70	9.3	7.66	7.16	7.8
ALUMINUM (*)				0.13			
ANTIMONY (*)				< 0.050			
ARSENIC (0.5)				< 0.005			
BORON (5.0)				< 0.050			
BARIUM (1.0)				< 0.020			
BERYLLIUM (*)				< 0.005			
CADMIUM (0.005)	< 0.01	< 0.01	< 0.01	< 0.002	< 0.005		0.01
CHROMIUM (0.05)				< 0.010			
COBALT (*)				< 0.010			
COPPER (1.0)	< 0.01	< 0.01	< 0.01	0.020	0.02		< 0.01
CYANIDE (0.2)							
IRON (0.3)	0.129	0.112	0.088	0.234	0.48	0.03	0.438
MANGANESE (0.05)	0.043	0.031	0.595	0.013	0.35	0.17	0.158
MERCURY (0.001)							
NICKEL (*)				< 0.020			
LEAD (0.05)				< 0.002			
SELENIUM (0.01)				< 0.100			
SILVER (0.05)							
STRONTIUM (10 Bg/L)							
TIN (*)				0.50			
URANIUM (0.02)							
VANADIUM (*)				< 0.010			
ZINC (5.0)	0.071	< 0.01	0.021	0.030	0.020	< 0.005	0.018
COLIFORM (10/100 ML)				0.200			
FECAL COLIFORM (0)							
*NO RECOMMENDED LIMIT							

TABLE B-10 (cont'd)
Groundwater Chemistry

LOCATION/PROJECT DEPTH DATE PARAMETERS IN MGL (CDNS) TIME	Downing St. Well Redmond Dec. 1976	Main St. Well Redmond Dec. 1976	East No. 1 Well Wabana Dec. 1976	No. 3 Yard well Wabana Dec. 1976	Hospital Well Wabana May 1980	Subdivision Well Wabana Oct. 1983	No. 4 Yard well Wabana Dec. 1976
SODIUM (*)							
POTASSIUM (*)					88.64		
CALCIUM (*)							
MAGNESIUM (150)	31.03	38.01	32.16	46.46	23.43	26.8	44.09
HARDNESS (As CaCO ₃) (*)	6.149	4.23	6.55	9.401	4.817	6.6	5.61
ALKALINITY (As CaCO ₃) (*)	103.17	115.46	109.8	155.25	87.63	33.0	138.04
SULPHATE (500)	116.2	146.2	52.0	145.4	155.8	250	115.4
CHLORIDE (250)					26	25	
FLUORIDE (1.5)					40	60	
SILICA REACTIVE (*)							
TOTAL PHOSPHORUS							
PHOSPHATE ORTHO (0.2)	0.056	0.066	0.060	0.070			0.112
TOTAL PHOSPHATE							
TOTAL NITROGEN							
NITRATE & NITRITE (As N) (10.0)	0.026	0.008	2.22	0.551	0.297	0.35	0.055
KJEL NITROGEN	0.374	0.174	0.033	0.125	0.360		0.075
AMMONIA (As N) (0.5)							
SURFACTANTS							
TOTAL ORGANIC CARBON (*)							
CHEMICAL OXYGEN DEMAND							
HUMIC ACIDS	7.07			3.86			2.6
HYDROCARBONS							
PHENOLS (0.002)							
TOTAL DISSOLVED SOLIDS (500)							
SUSPENDED SOLIDS (*)							
COLOR (15 TCU)							
TURBIDITY (5 JTU)					5		
CONDUCTIVITY UMHO/CM (*)	449.16	367.43	416.41	442.59	195	15	7.5
FIELD TEMPERATURE (50°C)					497.2		362.08
FIELD PH (UNITS) (6.5 - 8.5)							
LAB PH (UNITS)	8.16	7.86	6.28	7.96	7.78	6.5	7.96
ALUMINUM (*)							
ANTIMONY (*)							
ARSENIC (0.5)							
BORON (5.0)							
BARIUM (1.0)							
BERYLLIUM (*)							
CADMIUM (0.005)							
CHROMIUM (0.05)		< 0.01	0.01	< 0.01			0.01
COBALT (*)							
COPPER (1.0)							
CYANIDE (0.2)	< 0.01	< 0.01	0.100	< 0.01	0.011		0.01
IRON (0.3)							
MANGANESE (0.05)		0.523	0.195	0.067	4.746	0.15	2.07
MERCURY (0.001)	0.129	0.117	0.337	0.238	0.434	0.65	0.65
NICKEL (*)							
LEAD (0.05)							
SELENIUM (0.01)					< 0.01	< 0.01	
SILVER (0.05)							
STRONTIUM (10 Bg/L)							
TIN (*)							
URANIUM (0.02)							
VANADIUM (*)							
ZINC (5.0)	0.029	0.021	0.037	0.021			
COLIFORM (10/100 ML)							0.023
FECAL COLIFORM (0)							
*NO RECOMMENDED LIMIT							

- **Bell Island HU**

From one analysis on each of six wells the groundwater in this unit appears to be characterized by:

- . fresh (conductivity 300-500 umho/cm)
- . alkaline pH range 7.6 - 9.3
- . relatively low but detectable concentrations of nutrients in the form of nitrate and total phosphorus
- . relatively elevated alkalinity (100 - 179 mg/l).
- . iron and manganese at generally low concentrations except in the Bennett well.
- . parameters monitored for do not exceed the maximum acceptable concentrations (MAC) of the Guideline for Canadian Drinking Water Quality (1978)(CDWS) except sporadic occurrences of pH, iron and manganese.

- **Redmond HU**

From one analysis on each of three wells, the groundwater in this unit appears to be characterized by:

- . fresh (conductivity 367 - 449 umho/cm).
- . alkaline pH (7.8 - 8.2)
- . relatively low concentrations of nutrients.
- . iron (.99 - 0.52 mg/l) but more predominately manganese (0.12 - 0.16 mg/l) at levels exceeding MAC within CDWS.
- . relative elevated alkalinity (116 - 146 mg/l).
- . parameters monitored for do not exceed MAC limits except cadmium once (0.01 mg/l).

- **Wabens HU**

From one analysis on each of five wells, the groundwater appears to be characterized by:

- . fresh (conductivity 362 - 497 umho/cm)
- . variation around neutral pH 6.28 - 7.96 units
- . nutrient concentrations still low and detectable; but East No 1 well has elevated Nitrate as N of 2.22 mg/l.
- . alkalinity lower and more variable than in the other two HU's (52-250 mg/l).
- . iron (0.067 - 4.8 mg/l) and manganese (0.24 - 0.65 mg/l).
- . parameters monitored for do not exceed MAC level, except sporadic concentrations of cadmium, iron and manganese.

The data set is too small and "piecemeal" to run statistical analyses in order to separate out the characteristics of each unit. The only one distinguishing characteristic noted is the higher alkaline pH range for the Bell Island and Redmond HU's.

There is no evidence of salt water intrusion in the wells sampled. Of interest are the relatively high concentrations of calcium and bicarbonate, yet whole rock analysis shows no limestone and the limited calcium is tied up in fossil shells.

SECTION C HUMAN CYCLE

C-1.0 INTRODUCTION

"Human activities take place in conjunction with, not in isolation from, the many processes operating in nature, people are only one agent of change in a continually evolving environmental system. However, given the scale of many of the transformations initiated by human activity and the rapidity with which they take place, they tend to produce significant and highly visible impacts on the natural environment" (Statistics Can., 1986).

In order, to effectively manage the fresh water resources of Bell Island, it then becomes of paramount importance to understand the character of human activities through time. In the case of Bell Island, these activities have taken place over a rich and varied history. The island entered the stream of Canadian history with the first human activity around 1610, in the form of European fisherman. It remained an integral part of the fishing economy of Conception Bay until 1895 with the onset of iron ore mining which continued through to the mid 1960's.

The purpose of this section is to: 1) determine the type and extent of the human activities which have and are occurring, 2) assess the resultant demands and stress placed upon the water resources and 3) attempt to predict future growth trends and water demands for the next 25 years.

C-2.0 HUMAN CYCLE

Given the approach of this report in understanding drainage basin processes through the use of "cycles", it proved advantageous to discuss human activities in a similar manner.

The term "Human Cycle" is used in this report to define all activities controlled by man. This type of cycle is described by Chorley and Kennedy (1971) as a Control System; being defined as a process-response system in which the key components are controlled by some intelligence. Figure C-1 denotes one view of this cycle referencing it as the civilization "engine" (Stumm & Morgan, 1981). This "engine" converts resources into products for the economy which then ultimately become waste. Some of the wastes may be recycled but most will be dispersed into air, water or soil. The faster the engine runs the larger the waste stream. The control or regulator of the cycle is the political society. Our

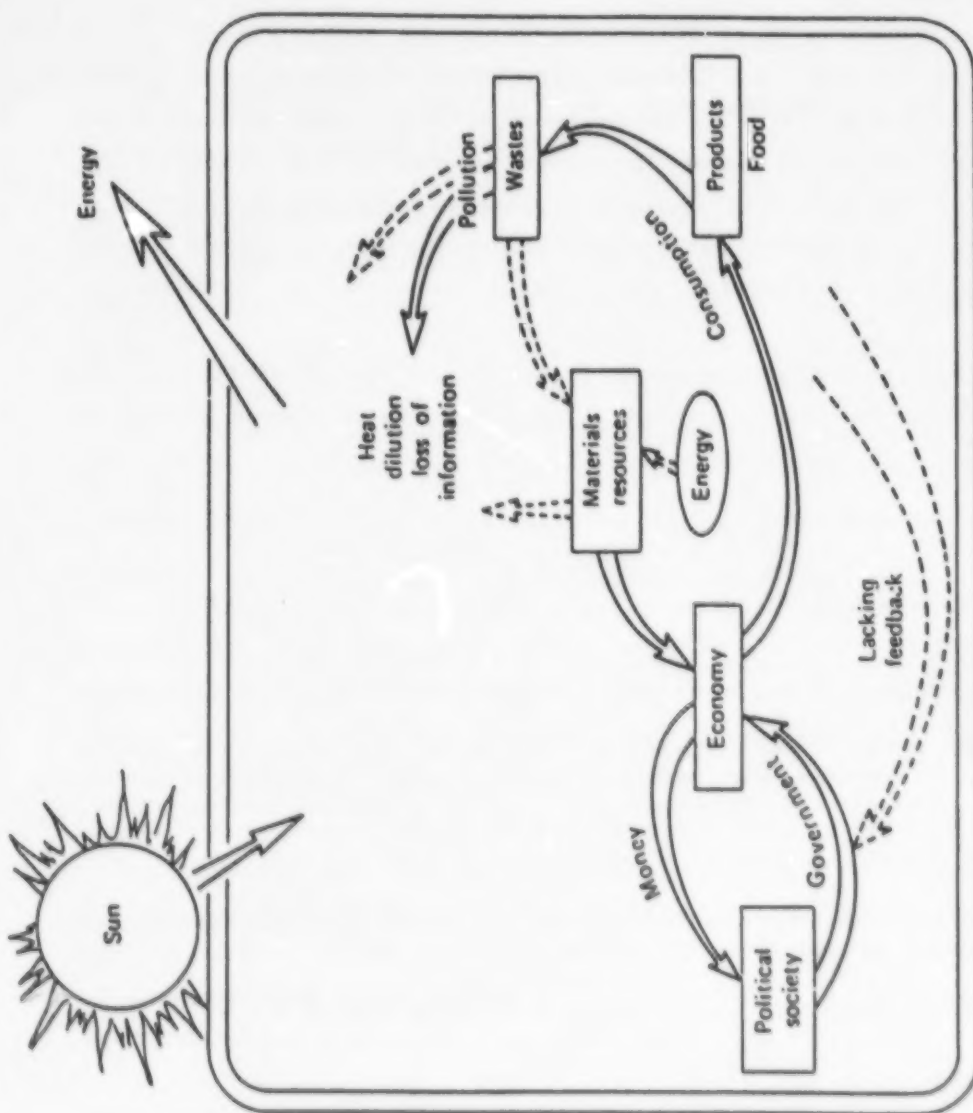


FIGURE C-1
"CIVILIZATION ENGINE"

economy with its capital - intensive production appears to function satisfactorily only under the condition of capital flow increase, leading to enhanced production, acceleration of hydrogeochemical cycles and increased wastes.

To discuss the Human Cycle effectively and within the context of a format already in use, the "STRESS" statistical framework is utilized. This is the acronym for the Stress-Response Environmental Statistical System used by Statistics Canada in their reports on the State of the Environment for Canada. This approach organizes statistics in a way that categorizes the relationship between humans and the other elements of the ecosystem; thereby reflecting the dynamic elements of environmental processes.

Within the organizational framework is the identification of "Environmental Stress Statistics" which measures the pressures placed on the environment by human activities through four principal activities, namely:

MINING CYCLE - encompassing the extraction and depletion of non-renewable resources (metallic & non-metallic minerals, fossil fuels).

HARVESTING CYCLE - encompassing activities which exploit the renewable resource base: agriculture, forestry & fisheries.

RESTRUCTURING CYCLE - encompassing the scope and nature of human activities involved in reshaping the environment for our social and economic well being, including urbanization, water supply systems, transportation/transmission networks, etc.

WASTE CYCLE - encompassing the generation of wastes from all production and consumption activities.

Each of these cycles are discussed in more detail below.

C-3.0 MINING CYCLE

By 1628, Bell Island was already associated with iron ore. John Guy sent rock samples to England for analysis, confirming ironstone. However, the mining boom did not materialize for nearly 300 years, (Neary, ?) although in the interim it was used for ship ballast.

The mining cycle on Bell Island encompassed:

- . the extraction of iron by underground or strip mines
- . the beneficiation of the ore prior to sale
- . transportation to market.

The market component was not located on the island and is therefore not discussed in detail.

C-3.1 Extraction

The Wabana underground room-and-pillar mines closed operation in June 1966, terminating a 73 year production history that began 56 years before the province joined confederation. During that time technology evolved from primitive pick and shovel techniques through various technological stages to advanced harnessing of diesel power. During this period, more than 80 million long tonnes of crude and beneficiated ore were shipped, leaving about 50 million as pillars and substantial proven and potential ferruginous reserves (Southey, 1969).

The iron formations were recognized as potentially economic deposits in 1892. Extraction first began by stripping in 1894 through two companies, Nova Scotia Coal and Steel Co. (Scotia) and Dominion Iron & Steel Corp. (Dominion). By 1905, both operations were underground and diminishing land reserves necessitated exploration of the submarine potential.

Along the land outcrop surface work removed most of the ore to the line of heavy cover. Between this line and the shore approximately 75 percent was taken by room and pillar mining methods. Minimum cover for submarine mining was 60 m from roof to sea bottom. Consequently, the area from submarine outcrops to this limit is intact.

Dominion Steel & Coal Corp. (Dosco) took over management of both companies in 1938 and their four non-integrated mines Scotia No. 3, No. 6 and Dominion No. 2 and 4 (mine head locations are noted on Map 2).

During the next 28 years of mining all mines were dry. The average daily pumping load of 1.6×10^6 litres came primarily from surface run-off and drilling. These conditions were considered exceptional and were in part explained by tightness of faults and the calcite or siderite filling of discontinuities. Submarine mining continued until 1966 when a

number of economic factors and declining markets resulted in closure. The final extent of mining is noted in Figure C-2 extending out some 4.3 km downdip from the island outcrop and covering some 15 km² (Gross, 1967).

This area forms barely 1/10 of the total 180 Km² area which is favourably suggested as containing ore reserves. Total ferruginous reserves in all beds are in the hundreds of millions of tonnes, the real potential depending on the average grade desired. Small tonnages with 48% Fe are recoverable in the land area under heavy cover.

C-3.2 Beneficiation

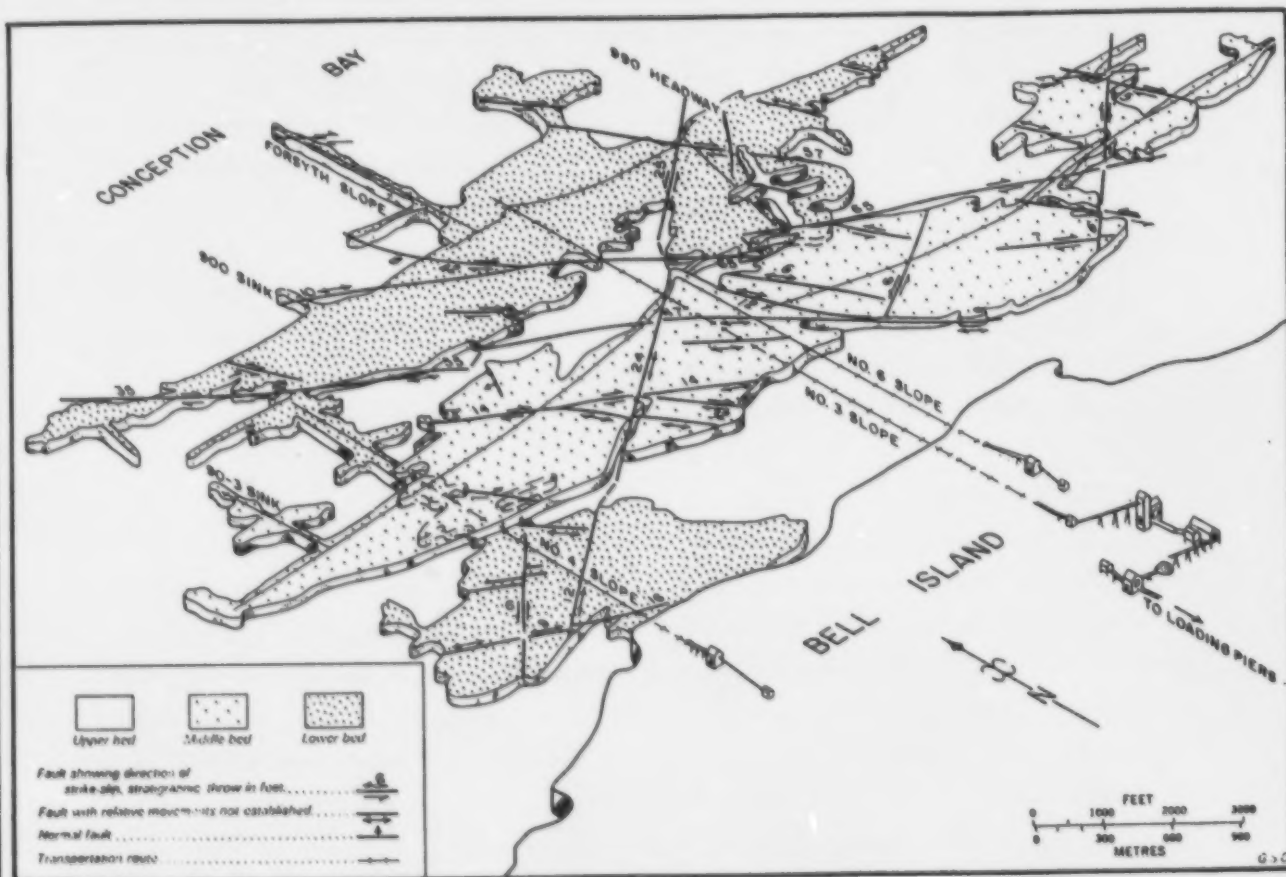
In 1938, preparation of the mined ore prior to sale consisted primarily of four crushing plants (Southey, 1969). In 1955, the plus 0.48 cm material was directed to a heavy media (S.g 3.15) wash plant (located Map 2). Approximately, 10% of the feed was float and went to waste. The remainder was sent to a sizing plant for crushing and sizing into three products: coarse (+2.5 cm), rubble (-2.5 + 1.3 cm) and beneficiated fines (1.3 + 0.48 cm). The -0.48 cm material went to a dewatering classifier of which 2 percent of the feed was slimes which went to waste.

Therefore, beneficiation forms a main regulator within this cycle separating the product (which is temporarily stored awaiting delivery to market) from waste rock which is sent to permanent disposal sites. These disposal sites are discussed in Section C-6.3.

C-3.3 Transportation

In 1895, a shipping pier (Scotia Pier) was constructed on the south side of the island (note Map 2) connected to the workings by a 3.2 Km endless rope, double track tramway. By 1938, an additional shipping pier (Dominion Pier) was constructed. In 1951, improved surface transport of ore was undertaken through construction of roads from all the mines to the stockpiling area above Scotia Pier and introduction of 20 tonne diesel trucks.

After construction of the wash plant in 1955, the road network was superseded by 2.7 Km of 0.9 m belt conveyor with 820 tph capacity and single boom staker equipment. In addition, Scotia Pier was expanded to handle 32,000 tonne ore tankers (Southey, 1969).



SOURCE: Gross, G.A., 1967; Geology of Iron Deposits in Canada, Vol. II; Geological Survey of Canada (GSC) Economic Geology Report No. 22; Adapted from Norris, D.K.; 1957; GSC, Courtesy of Dominion Wabana Ore Limited.

FIGURE C-2
EXTENT OF UNDERGROUND MINE WORKINGS
BELL ISLAND

C-3.4 Markets

All markets are located off-island. In 1895 the first shipment of iron ore was made by the Scotia company to its Ferrona Steel works in Pictou, Nova Scotia. By 1949, the year Newfoundland joined Confederation, Wabana constituted 43.4% of Canada's total iron ore production of 3.28 million tons. The primary markets were the steel works in Sydney and Pictou, Nova Scotia.

C-4.0 HARVESTING CYCLE

This cycle encompasses activities which exploit the renewable resource base; namely; agriculture, forestry and fisheries. Although the latter component is outside the terms of reference for this study, it was the fisheries which started human activity on the island and controlled land based activities starting in 1610. The island remained an integral part of the fishing economy of Conception Bay until the late 1890's when mining took over (Neary, ?).

C-4.1 Agriculture

The development of large scale agricultural activities is made difficult by environmental constraints. Precipitation is both excessive and increases throughout the growing season thus reducing the chance for crops to dry out. Simultaneously, the availability of heat for crop growth during the growing season is submarginal as exemplified by the at best 1700-1950 growing degree day units per season versus the minimum 2000 units generally accepted for successful field agriculture (Gorman Butler, 1976). Despite the poor climate farming was a relatively important economic activity on the island until the late 1800's, when it became of secondary importance with commencement of mining. Unfortunately, very little data is available on these early activities.

Traditional agriculture/farming declined dramatically after 1935 (Table C-1) so that by 1951 it was only of very minor commercial significance. By 1971, only four commercial farms were reported. By 1976, this had declined to two commercial farms (Gorman Butler, 1976) including: a sheep/cattle operation on lighthouse road and a pig farm near the ferry terminal. There is a community pasture located in the north portion of Wabana where some families grow root crops and even rear animals (sheep,

cattle, goats) for domestic use. A considerable amount of land formerly devoted to agriculture is now covered by poor scrub.

If agricultural expansion does occur it will be in the south and eastern portions of the island where soil and climate conditions are most favourable (Gorman, Butler, 1976).

Horticultural activities have shown a rising trend. Between 1970 and 1976, 16 commercial green houses have been established providing 2800 m² of greenhouse space. At the same time, three more were under construction and two in planning. The principal crop is tomatoes which are marketed in the island and the Avalon Peninsula.

Given the decline in agriculture prior to 1951, it is probable that modern pesticide/herbicide sprays have not been used on the island.

TABLE C-1
AGRICULTURAL ACTIVITIES
BELL ISLAND, 1935-1966 (after Gorman Butler, 1976)

	1935	1951	1961	1966
Cattle	227	105	37	50
Pigs	236	15	-	8
Sheep	586	323	-	-
Hens; chickens	7,746	1,039	276	259
Fodder Crops	288 hect	138 hect	6.5 hect	13.4 hect
Pasture	207 "	55 "	4.1 "	-
Field Roots	185 "	23 "	0.81 "	1.6 "

C-4.2 Forestry

Woodland presently occupies 48.7% (1320 hectares) of the island being primarily restricted to the western portion. Combined with scrub grassland and bogs it constitutes some 59.6% of the surface area. The timber resource is primarily stunted black spruce and balsam fir. Even with this high acreage, forestry in general has been of no commercial significance to the island's economy (Department of Municipal Affairs and Housing, 1981) except for a few references to ship building in the past. At present, no permanent commercial establishment utilizes this relatively small scale and poor quality timber resource. The main reasons appear to be that bedrock exposures, soil conditions, soil heaving, drainage and

exposure have resulted in long growing cycles, low yields and stunted growth.

C-5.0 RESTRUCTURING CYCLE

The scope, nature and fluctuations in human activities involved in reshaping the environment for man's social and economic well-being are discussed within this section. As with all components within this report, the interrelationship with other cycles necessitates some overlap with previous discussions. This cycle is broken down into three components:

- 1) Land Use/Conversion
- 2) Transportation Networks
- 3) Energy Sector
- 4) Water Supply Systems

These are discussed further in the following sections. However, the restructuring results from increased population, which is discussed first.

C-5.1 Population

The island was first settled in approximately 1610 no data is available on those early years; but it is expected that the fortunes of the community waxed and waned with those of neighbouring Conception Bay settlements, as they were tied principally to fishing. By 1845, the island had a population of 338 (Table C-2).

The population seems to have increased slowly and steadily and almost doubled over the period 1850-1890. The advent of mining in 1895 created a quick rapid rise of 86.2% to 1,320 people in 10 years between 1890-1900. This was followed by a 133.6% rise over the following decade to 3,084. The rise continued so that by the first census year in 1935 the population stood at 6,157.

The rise continued unabated, peaking in 1961 at 12,281. This was followed by a rapid population decline on both the island and Wabana by almost 40-50% during the period of economic uncertainty associated with mine closure in the 1960's. Despite the first major layoff in 1959, significant declines did not occur in the following six years as many local people believed that the layoff would be temporary. The major decline began in 1966 following complete closure of mining operations and relocation of unemployed miners.

TABLE C-2

POPULATION OF BELL ISLAND
1845 - 1987

	Total Population	Bell Island Change		Total Population	Wabana Change	
		Number	Percent		Number	Percent
1845	338	-	-	N/A		
1857	428	90	26.6	N/A		
1869	504	76	17.8	N/A		
1874	576	72	14.3	N/A		
1884	651	75	13.0	N/A		
1891	709	58	8.9	N/A		
1901	1,320	611	86.2	N/A		
1911	3,084	1764	133.6	N/A		
1921	4,357	1273	41.3	N/A		
Census Year						
1935	6,157	1800	41.3	N/A		
1945	8,171	2014	32.7	N/A		
1951	10,291	2120	26.0	6,460		
1956	11,724	1433	13.9	7,873	1,413	21.9
1961	12,281	557	4.8	8,026	253	3.2
1966	9,090	-3191	-26.0	7,884	-142	-1.8
1971	6,079	-3011	-33.1	5,421	-2,463	-31.2
1976	5,347	-732	-12.0	4,745	-676	-12.5
1981	4,861	-486	-9.0	4,254	-509	-10.7
1986	4,609	-252	-5.2	4,057	-197	-4.6
1987	4,348	-261	-5.7	3,782	-265	-6.6

- N/A - not applicable as Wabana not incorporated until 1950
- Census of Newfoundland and Labrador for 1935, 1945
- Census of Canada 1951 to 1986
- 1845 - 1921 data from Gorman Butler (1976)
- 1987 data from Challenge '87 seed program group sponsored by local church groups

The last ten years (1976-1987) have seen a slow but continued erosion in the population base averaging 1.6% per year. This is thought to represent the out-migration of young people (Department of Municipal Affairs and Housing, 1981) into the nearby St. John's urban region.

Wabana was incorporated as a town on August 29, 1950. Prior to this, there had been several elected Councils followed by a number of local road boards to deal with the maintenance of certain roads. In 1958, the Town had a municipal plan but it was not implemented due to virtual economic collapse (ibid). Wabana is the dominating and the only incorporated community on the island. While the Wabana Municipal area (note Map 2) occupies approximately the northeastern half of the island, other settlements including Lance Cove, Bickfordville and Freshwater are located in the unincorporated area to the southwest.

C-5.2 Land Use/Conversion

The rich and varied history of the island has altered natural land use patterns significantly in certain areas. However, as this is closely linked to population trends, there is also a cyclic pattern in land use.

The Gorman Butler (1976) report undertook an in-depth analysis of land use on the island at a 1:2,500 scale which represents a "snapshot" of conditions in time. Given the absence of any major population increases or other notable activities since that time the data from that report probably reflects existing conditions. The associated colour coded map is not reproduced for this report. The quantitative data is reproduced in Table C-3. A description of the categories includes:

- 1) Of note is that urban/suburban land use only covers approximately 10 percent of the island. Residential lands are found predominately over the northeast half of the island although clusters also characterize smaller communities of Freshwater, Bickfordville and Lance Cove in the southwest half of the island.
- 2) Agricultural land use, encompassing cropland, horticulture and improved pasture encompass 8.5 percent of the island. Cropland is distributed mainly in a small scattered plots over the south sector. This area has declined considerably in recent years reverting to rough pasture, scrub grassland and woodland.

TABLE C-3

LAND USE - BELL ISLAND 1975
AFTER GORMAN BUTLER & ASSOC. 1976

LAND USE

<u>USE</u>	<u>HECTARES</u>	<u>PERCENTAGE OF TOTAL</u>
Residential	183.5	6.6
Commercial	49.1	1.8
Institutional	29.4	1.0
Recreational	10.4	0.4
Cropland	44.1	0.7
Horticultural	2.0	0.1
Improved	211.1	7.7
Rough Pasture	218.1	10.1
Scrub Grassland	276.4	10.0
Woodland	1,313.4	48.7
Marsh and Bog	24.3	0.9
Unproductive Land	200.0	10.2
Water	<u>44.6</u>	<u>1.8</u>
TOTAL	2,752.4	100.0

- 3) Rough pasture encompassed abandoned or neglected fields while scrub grassland was in the advanced stage of transition to woodland.
- 4) Some 59.6% is still covered with woodland, marsh, bog and scrub grassland, located predominately over the southwest sector of the island.
- 5) Unproductive land encompassing 10.2% of the island involves mine dumps, land disrupted by former mining operations and steep coastal cliffs.

C-5.3 Transportation

There are 52 Km of roads in Wabana. All principal collector roads on the island, including those servicing unincorporated areas are paved and maintained by the Department of Transportation and Communication. However, there are districts predominately within the urban areas, which as yet are only serviced by gravel roads.

A sand/salt mixture (75%/25%) is applied to island roads in the winter, except the steep hill to the Ferry terminal where pure salt is used. This requires stockpiling approximately 1800 tonnes of salt annually at the depot (Map 2).

The abandoned transport network used by the mines was discussed in Section C-3.3.

Three automobile service stations are present on the island, all located within Wabana (note Map 2); each has gasoline service. Underground storage tanks are used for storage. Information on the type and capacity of the tanks was difficult to obtain. It is believed that all storage tanks are constructed of steel and have a capacity of at least 90,900 litres/station.

There have been two reported oil spills associated with these stations to date, itemized as:

- . February 1974 - 31,800 L furnace oil spill from the Golden Eagle Service Station
- . February 1979 - 136 L of gasoline spilled at Upshall's Service Station

There is an existing airstrip on the island, constructed in the winter of 1956-57 (Map 2). It was upgraded in 1982, and is currently used by small planes on a sporadic basis. No de-icing fluids are in use, nor are there facilities for the storage of hydrocarbons.

C-5.4 Energy Sector

All electrical power is generated off-island. A submarine cable is used for transmission to the island with landfall near the ferry terminal. Transmission over the island is above ground along the existing road network. It appears that herbicides are not in widespread use along these right-of-ways.

Two petroleum storage tank farms are located on the island, operated by Irving Oil Ltd. and Esso Ltd. (note Map 2 for location). The tanks are used primarily for the storage of furnace oil and gasoline. Approximately, 455,000 litres of furnace oil maybe stored on site during peak supply periods. Product shipment to these installations are via marine and road tankers.

The tanks are checked every two to three years for structural integrity. Containment ponds are provided, although the capacities are unknown. One reported spill of 1370 litres was reported at the Irving Oil tank farm in January 1977.

Most of the homes on the island utilize oil for heating, and have their own storage tanks.

C-5.5 Water Supply Systems

As per the terms of reference, Nolan, Davis & Associates have conducted a complete review of data on the existing water supply system for this study. Included in the review were site visits to Bell Island to inspect the system and gather information on the demand requirements, potential problems, future expansion/upgrading, etc. As well, interviews were held with local works personnel, officials from the Town of Wabana, operators of local service district pumping stations, and representatives of various Departments of the Government of Newfoundland and Labrador, including: Health, Municipal Affairs, Environment, Housing, and Development.

C-5.5.1 Utilities

C-5.5.1.1 Incorporated District - Wabana

The town of Wabana obtains its potable and non-potable water supply solely from a groundwater source through 14 relatively deep bedrock wells scattered throughout the Town (note Map 2 for locations and local names). Two of these wells are dedicated for the use of the Vocational School and hospital.

A spread sheet giving the details of the wells, estimated yields and pumping demands is presented in Appendix D. It must be stressed that until recently very little data was recorded on the status and background of each well. The data has been prepared utilizing the Lotus 1-2-3 software.

It is expected that some residents maintain their own private wells as a backup source in addition to being connected to the municipal system.

A summary of pertinent data provided in the spread sheet is presented in point form as follows:

- . The well system provides fresh-water to approximately 1100 residential households, 20 institutional buildings (schools, churches, community halls, municipal buildings, etc.), and 40 commercial establishments (stores, restaurants, service buildings, gas stations, etc.) and 3 industrial plants (highway garage, municipal works building and small fish storage plant).
- . The wells are typically deep boreholes ranging from 73 m to 162 m; thereby drawing solely from the bedrock aquifer.
- . Borehole diameter is typically 150 mm.
- . Little information is available on the sustained yield capacity of the wells. Pumping tests on isolated wells (mostly recent installations) show predicted yields in the range of 50 to 80 litres per minute.
- . Number of households and other buildings serviced by individual wells varies from approximately 25 to 200 units.
- . Subsequent peak demands range from 50 lpm to 335 lpm. The following wells are reported to have the highest demand: Main Street, No. 4, rock cut (used in conjunction with Main Street).
- . All wells have submersible pump installations with motor capacities ranging from 1.1 Kw to 11.3 Kw.

- Pressure imbalances have been a problem with system in the past due to haphazard developments. Recent efforts to correct this problem have included the installation of surface pressure tanks at a number of well heads with positive results.
- The Department of Health executes regular inspections of all sources of water supply. The most recent checks indicate/satisfactory bacterial counts.
- Storage facilities other than the limited capacity in the pressure sustaining tanks are typically not used in the system. A 54,000 litre elevated tank forms an ancillary component of the Quigley Lane pump station and is used in a reserve capacity.
- Water quality problems are especially prevalent at the end of "dead end" distribution lines. Odour (H_2S) and silt problems are common when the pumps are regularly shut down.
- Treatment of the water is typically not provided, including chlorination. The Normone Crescent pump station and Quigley Lane is equipped with surface tanks vented to the atmosphere to remove hydrogen sulphide gases.
- The Davidson Street and Railroad wells receive most of the complaints about H_2S odour.
- Two wells believed to have been drilled by Dosco (Davidson Avenue and Main Street) for which there are no available records are reported to be virtually inexhaustible by local authorities (Gorman Butler, 1976).

In terms of the distribution system, much of it is the remnant of a system of 10 cm mains installed by the mining company to serve its industrial residential facilities. Most of the houses on The Green, Bennett Street and The Ridge are supplied by this original network.

Overall, the quality and size of the system varies in each location, much of it being installed in an era when there was little government control. The network contains many incongruities arising from the unplanned nature of many of the installations and the fact that with considerable ingenuity extensions were made to existing systems on an adhoc basis. There are reports of dwellings with illegal connections to old mining Company waterlines and of service lines running through houses connected in series. As a result, many residents could not obtain enough water in winter because it became frozen before reaching their residence

(Department of Municipal Affairs and Housing, 1981). In most cases, however, the depth of burial seems to be satisfactory and there is little problem with freezing of main lines during winter.

Supplementing this system is a 91 X 10⁶ litres surface water reservoir on Freshwater Brook (Map 2) to provide flow rates sufficient for fire fighting flows. At the present time this system is partially operational, but experiences low pressure as a surge tank is not on-line. A 72,000 litre storage tank is located along the water line from the dam and is presently being refurbished for such a use.

A 15.2 cm cast iron main (known as the Dam Line) from the surface water reservoir provides fire fighting capacity to much of the community and hydrants are strategically located for this eventuality.

The extent of the distribution system from each well head has not been accurately determined by the Town of Wabana at this time. However, it is understood that through a series of shut-off valves all the wells and distribution lines are interconnected.

C-5.5.1.2 Unincorporated Area - Lance Cove

The unincorporated area of Lance Cove contains the three main communities of Lance Cove, Brickfordville, and Freshwater. In past years, these communities contained a larger population base, whereas today they are sparsely populated.

The entire area contains approximately 170 households. There are four multiple-user wells (described in Appendix D) which service a total of approximately 75 households. The locations of these wells are shown on Map 2. There is another deep well capable of multiple residence use and is located in the recreational park in Bickfordville.

The remaining residences in the unincorporated districts use single source supplies. The most common source is a drilled well. Other sources include dug wells, mainly in the Freshwater area and isolated springs in Bickfordville.

C-5.5.2 Demand

Since mine closure in 1968, the main demand placed on the island's groundwater supply has been for the servicing of residential and limited commercial/institutional facilities on the island. The former

facilities include a hospital and vocational school and some commercial enterprises which are superior to many which might be found in other communities of a similar size. This is one legacy of the island's industrial past. At present, there are no industrial users other than the works garage and fish plant.

Unfortunately, there are no flow meters on any of the wells so identification of daily and peak flows must rely on extrapolations of NDAL's experience elsewhere in Newfoundland. The present average daily demand for water is estimated in Table C-4. Utilizing 365 days per year to estimate annual demands for households, hospitals, and restaurants and 250 days per year for stores, offices, and meeting halls, the estimated total annual demand placed on the islands groundwater resources is 5.0×10^8 litres (500 DAM³).

As is evident, the main demand is for households. If it is assumed that this demand could be as high as 380 litres/person/day then the annual demand could rise to 594 DAM³.

C-6.0 WASTE CYCLE

This section makes specific reference to the three main waste streams which have and/or are being generated on the island; specifically mining wastes, municipal solid wastes, and municipal liquid wastes.

The "waste" stream generated by air emissions from the thermal energy generation sector off-island (but which influence precipitation chemistry on the island) has been discussed in Section B. The generation and consequences of the waste stream from transportation activity through air emissions of carbon monoxide, nitrogen oxides and lead, is outside the scope of study. There are no large manufacturing concerns on the island which would create a special waste stream for consideration. Commercial and institutional wastes have been lumped in with the two municipal streams discussed below. Storm runoff from developed areas and roads is a pertinent waste stream. However, due to the minimal data available it has been lumped in with municipal liquid wastes.

TABLE C-4
ESTIMATED DAILY WATER DEMAND
BELL ISLAND 1988

<u>USER</u>	<u>DEMAND (litres/day)</u>
Households	
1300 homes at 900 l/day/home	1.17 X 10 ⁶
Schools (Elementary to High School)	
1600 students & staff at 75 l/day/person	0.12 X 10 ⁶
Hospital	
50 beds at 800 l/day/bed	0.04 X 10 ⁶
Senior Citizens Home	
40 units at 400 l/day/unit	0.016 X 10 ⁶
Stores (Commercial outlets)	
40 units at 200 l/day/unit	0.005 X 10 ⁶
Lounges and Restaurants	
4 units at 1500 l/day/unit	0.006 X 10 ⁶
Offices Buildings	
10 units at 200 l/day/unit	0.002 X 10 ⁶
Agricultural (Livestock)	
estimated at	0.005 X 10 ⁶
Fishery	
estimated at	0.005 X 10 ⁶
TOTAL DAILY DEMAND	1.38 X 10 ⁶

C-6.1 Municipal/Domestic Solid Waste (MSW) Stream

The town of Wabana has operated a municipal landfill at the northwest corner of the island near Gull Island South Head (note Map 2) for several decades.

The waste handling/disposal system incorporates three components:

- 1) Garbage collection is once every two weeks in Wabana although this is considered inadequate in the summer. There is no garbage collection in the outlying areas and residents have to take care of their own disposal.
- 2) Since 1979, the town has utilized a tee-pee style incinerator at the disposal site for burning the combustible solid wastes. It is located immediately north of the landfill. The system is fairly simple with no control of stack emissions and a bottom load out for removing the ash. It's location at the downwind end of the island, near the coast is thought to aid in quickly dispersing the air emissions over low populated areas most of the time.
- 3) The ash residue, and non-combustible wastes are disposed of at a landfill site situated immediately south of the incinerator along the shoreline, within what appears to be a portion of an abandoned strip mine. The placement of soil cover over the debris appears to be carried out only on a very limited scale. No factual records were found on landfill development. From personal conversations it would appear that it developed in a northerly direction with access roads for the dump at various intervals along the main road. Old waste rock or strip mine spoil material was used at times for cover material.

Given the non-industrial nature of the community, the water chemistry of the leachate draining from this disposal area should closely resemble data reported in the literature.

Given the northwest dip of the rocks and their relatively low permeability it is expected, on a first order-of-magnitude basis, that are leachate will be discharged directly into the sea. There is no leachate collection and treatment system presently installed.

C-6.2 Municipal/Domestic Liquid Waste Stream (MLW)

The long term problems associated with the handling of this waste stream can be summed up by noting that in 1961 the census for Bell Island

recorded an all time high of 12,281 people - yet this was in a town that still did not have a central sewer system.

At present on Bell Island there are two main but separate sewer systems both of which discharge directly into Conception Bay at two outfalls (note Map 2). Both were installed in the early 1960's.

The major system is an 20.3 cm A.C. sewer which runs through several streets in the Ridge and Town Square and is collected at Compressor Hill where it runs through a 30.5 cm line approximately 1200 m to an outfall at Gull Island South Head. The infrastructure of this system and the outfall are of 1940 vintage. Another smaller system of 6 manholes and associated 20.3 cm sewer main is located in East No. 1 and is brought into the 30.5 cm outfall system mentioned above, servicing 11 buildings (Gorman Butler, 1976).

The second system services primarily the St. Edward's School as well as 17 other buildings. It consists of 10 manholes and associated 20.3 cm sewer main with a Smith-Loveless package treatment plant (capacity 60,560 lpd). The system was installed in the early 1980's and provides primary treatment only. The outfall is located approximately 300 m west of the ferry docking facilities (Gorman Butler, 1976).

All told, these systems service approximately 30% of the households, commercial outlets and institutional buildings within the incorporated area of Wabana.

The older lines servicing the central and business districts of the town is apparently in a deteriorated state. There are reports of surcharging of the system during periods of peak runoff, indicating leakage within the lines.

The unserved areas of the town and the unincorporated area mainly use on-site septic tanks with disposal fields and/or grey water drains.

However, there are units known to discharge sewage into open ditches and low lying swampy areas. These units are mainly within the town of Wabana where failed and undesirable systems are much more prevalent than in the rural areas. This is probably a result of the low population density and larger land areas available for field beds in the latter.

In general, the hydrogeologic conditions on Bell Island are not considered ideal for normal below grade disposal fields due to a combination of thin, discontinuous, low permeable till, high rainfall and low evapotranspiration. The resulting increased frequency of saturated soil conditions reduces effective attenuation and enhances overland flow of effluent into surface streams.

On at least one occasion, the "Main Street" pumping well exhibited elevated total and fecal coliform bacteria. Following remedial work to a nearby septic system the bacterial concentrations reduced. Other isolated cases of suspected contamination have been reported to and investigated by the Department of Health.

The problems with the disposal of this waste stream have been well recognized in the past. Gorman Butler (1976) proposed a significant upgrading and expansion of this central system to service approximately 91% of the buildings in Wabana including some 840 buildings currently not being serviced. Only minor improvements to the sanitary sewer system have been made since the report was presented in 1976.

The lack of adequate sanitary service hinders the extensions of municipal water supply to some areas of the Town because the Department of Consumer Affairs and Environment requires that such extensions should not be made without the provision of sanitary sewers at the same time.

In all parts of the island, storm drainage is provided by a system of open ditches and culverts at the road sides. There are no reports of flooding and the system appears to be functioning effectively (Gorman Butler, 1976).

C-6.3 Mining Waste Stream

The waste stream associated with past mining activities is primarily concerned with tailings and coarse wastes from the mill as well waste rock from tunnel drainage and strip mining.

Very limited records are available on volumes of material, their land based disposal areas and the chemistry of waters draining from them.

Tailings

The tailings from the process mill was directed to an adjacent thickener and then piped initially to a land based disposal site located to the northwest, approximately half way to the shore (note Map 2). This area was apparently a depression created by previous strip mining activities and presumably lined with bedrock.

None of the municipal wells are located down topographic gradient from this site or along strike. There are however, a number of dwellings to the north, east and southwest, some of which likely have domestic wells as backup for central water. The number and location of these wells are not known. However, from personal conversations, it appears that they are in isolated locations and limited in number.

At a later date disposal of tailings was by an outfall directly into the sea at a point near Gull Island North Head (note Map 2). The high energy environment along this coast was apparently quite effective in dispersing the material, as no build up of tailings is noted along the shore.

Coarse Wastes

The coarse wastes disposal areas are centered predominately around the portals as well as in a band over the subcrop of the three ore seams when stripping occurred (note Map 2).

C-7.0 FUTURE DEVELOPMENT AND WATER DEMANDS

The long term development possibilities for Bell Island appear to be very limited. In the past, three major industrial activities have been identified with varying levels of feasibility research. The industrial scenarios included:

- . underground storage for domestic oil
- . pumped hydroelectric power generation
- . reopening of the iron ore mines
- . large scale greenhouse installation

All of the above mentioned potential projects hold a slim chance of realization. The main problem being the identification of markets for the product derived from the project. The potential is further diminished by Bell Island's isolation factor.

Discussions with various levels of government appears to confirm that the long term planning for Bell Island should be limited to the premise that continued residential usage will continue with the ancillary small commercial and institutional operations remaining in place to service the community. The local council would like to see a large government sponsored institutional operation such as a penitentiary boys school, etc. established on the island to provide some economic stability for the community.

Considering the trends in population, industrial activity, and land use, along with the hydrological aspects of the island, it appears the future water demands for the island will include the following:

- . residential, mainly single family dwellings
- . commercial, small shops, corner stores
- . institutional, schools, hospitals, potential large facility
- . light agriculture light fishery

Given the declining trend in the population, it is reasonable to assume that the total figure for water demand given in Table C-4 will diminish proportionally unless a major industrial or institutional development is established. Assuming that the sharp decrease shown in the population between 1986 to 1987 includes some gaps in information between the two methods of survey, it appears that the rate of population decline is in the range of 1 to 2 percent per annum. However, to apply typical trend statistics to predict future Bell Island population may be misleading. The following factors will affect any such forecasting:

- decreasing birth rates
- increased mortality rates.
- stabilization in the migration rates due to equity in homes but no market for resale.
- improvement or deterioration in the level of ferry service provided to the island.
- the attraction of the natural kinship among the community residents and subsequent reluctance to pull up roots and move to an unfamiliar area.

Based on the present level of development and dim prospects of additional growth on the island, it has been assumed that the population will continue to decline over the next 25 years to the year 2013. A decline in population of 1.0 to 1.5 percent per year is likely a reasonable figure to consider giving the statistic trend provided in Table C-2. Table C-5 provides a summary of predictions in population water demands through to 2013.

**TABLE C-5
FUTURE PREDICTIONS OF
BELL ISLAND WATER DEMAND**

Year	Population	Annual Water Demand(DAM ³)
2000	3700	420
2013	3000	347

SECTION D

WATER RESOURCE MANAGEMENT

D-1.0 INTRODUCTION

The close interrelationship which exists between a regional plan and water resources management cannot be underestimated. Together with energy, water is one of the major fuels of economic development. In fact, the first use of Bell Island was by fishing vessels in the late 1500's which called at the two ends of the island, both known as Freshwater, to take in supplies of freshwater.

Up to the present time management of the water resources on the island has been carried out principally by coping with problems case-by-case as each develops. By trying to solve problems after they develop effective remedial actions are more difficult and more costly to implement.

To break this cycle a good management control mechanism is needed. It should encompass the rational development of short, medium and long range practical management strategies.

For the effective management of any resource it is imperative that management goals be developed and put in place prior to, or at least early in, its utilization. In this regard management on the island will be facilitated by the fact that:

- 1) The resource being managed is "renewable".
- 2) Although development has occurred on the island, it is presently utilizing approximately 3.5% of the total replenishable resource; regional mining of the aquifers does not seem to have occurred to date.
- 3) Major land use alterations have been confined principally to the northeast end of the island.
- 4) The island experiences a large annual water surplus.
- 5) There is an absence of major toxic waste disposal sites on the island. Spoil piles associated with past mining activity, and municipal solid waste (MSW) disposal areas are present. Both types of sites are concentrated in the northeast sector of the island, coincident with urban/suburban land use.

- 6) The high vertical rise in topographic relief around the island ensures that as sea level rises, it will not flood any major low areas; which would result in dissection of the freshwater lense under the island.
- 7) There appears to have been an absence of the widespread application of pesticides/herbicides on the island.
- 8) The major water resource to be utilized on the island is groundwater which is virtually ubiquitous with wide areal distribution, as opposed to linear distribution and temporal variability of surface waters. In addition, groundwater storage can be developed in stages, borehole by borehole with the rate of growth being varied to match demand growth as it actually occurs. This ensures capital investment does not take place unreasonably in advance of need.
- 9) A major difficulty in water resources management within large systems is the discrepancy between where water is found versus where the demands are located. However, in the case of Bell Island, the sources and demands are relatively localized within a well defined area.
- 10) Although there is some local political jurisdiction split on the island which cross hydrologic boundaries, the island is small enough to be looked at in Socio-economic -political terms as one unit.
- 11) The stress being placed on the water resources of the entire Avalon Peninsula, has been recognized by the regulatory agencies. The Newfoundland Department of Environment in 1985-86 undertook a regional evaluation of water resources in the peninsula. The gathering of that data and its interpretation greatly facilitated the understanding of Bell Island for this investigation.

Therefore, this report and the following management recommendations are timely and if followed should provide a sound yet flexible base around which the rational management of the fresh water resources can be developed.

Throughout the following discussion, it has been recognized that resistance to any form of management is usually widespread and stems from the perception that regulation may impose real loses on individual users, even if the majority benefits. Effective management policies will therefore need to be simple, flexible, equitable and inexpensive to administer.

The remainder of this section is designed to initially summarize what is known about the resource itself, not only in terms of its present utilization but also its potential. This is followed by the development of various management strategies and schemes.

D-2.0 FRESH WATER RESOURCES

D-2.1 Resource Potential For Man

As previously noted, it appears that there is conservatively some 1×10^4 to 3.0×10^5 DAM³ of fresh water in storage on the island (assuming a 91 m depth boundary). Of this total, some 99 percent is groundwater stored in the bedrock aquifers and 1 percent is surface water stored in stream channels and lakes.

Conservatively it is estimated that some 8700 - 11,200 DAM³ infiltrates and recharges the bedrock aquifer annually. Some 9500 - 12,000 DAM³ annually moves as surface flow being transported by interflow and saturation overland flow mechanisms.

Water resources in general are utilized by man in a number of ways: 1) water supply, 2) energy, 3) attenuating contaminants, 4) navigation, 5) flood damage reduction, 6) fisheries resource and 7) recreational.

The fisheries aspect was outside the Terms of Reference of this study. However, initial discussions with fisheries personnel indicated that they did not regard the streams on the Island to form a valuable fisheries resource. This may be due in part to the steep slopes and waterfalls at the mouths of the streams.

Given the size of the streams, navigation and flood damage reduction are not valid, practical concepts on Bell Island. The remainder of this section discusses the other uses.

D-2.1.1 Water Supply

To assess the potential utilization of this resource for water supply, necessitates a determination of the "safe yield" of the system. Safe yield is defined as the amount of water which can be withdrawn annually without producing an "undesired" result. However, to quantify

"safe yield" implies a knowledge of parameters either outside the terms of reference for this study i.e. riparian flows for aquatic biological species, or those which at present cannot be quantified due to absence of pertinent data. The latter point is discussed in more detail in Section D-3.3.6. Given this constraint, the following discussion attempts to define, in order-of-magnitude terms, the potential for withdrawal of water from groundwater systems for water supply, discounting the impacts of such a withdrawal.

The surficial hydrostratigraphic units are not considered to be useful due to low permeabilities, in certain instances poor water quality (organics HU), the high potential for contamination and rapidly fluctuating saturated thickness. The main resource potential for water supplies lies within the bedrock hydrostratigraphic units as discussed below.

- Bell Island HU -

A total of 9 municipal wells are located in this HU. Well depths range from 60 - 162 m. Estimated yields from borehole records range up to 81 Lpm; although a number have unknown yields. Discussions with Mr. M. Hammond, a local driller, indicated no major difficulties in obtaining groundwater supplies of sufficient quantity and acceptable quality for domestic purposes within this unit.

Pump tests have been carried out on two municipal wells within this unit (Table D-1). Transmissivity values ranged from $1.3 - 2.8 \times 10^{-5} \text{ m}^2/\text{s}$ with resultant recommended pumping rates of 60 - 80 Lpm.

A comparison of available water chemistry data (Table B-11) indicated that of the parameters monitored, all were within the maximum acceptable concentrations (MAC) of the Canadian Drinking Water Standards and Objectives (CDWSO) (1978) except manganese and at times colour.

- Redmond HU -

Only 3 municipal wells have been drilled into this unit; no logs or estimated yields are available. Unfortunately, no pump tests have been completed on these wells.

The hydrogeological assessment (Section B-5.3.2) suggests a potential for relatively high yields. This is supported by the Gorman-Butler report (1976) which indicated that two of the highest capacity wells in the Wabana System, are the Davidson Ave., and Main St. wells. They were believed to have been drilled by DOSCO and are reported to be virtually "inexhaustible" by local authorities. Both are drilled into this HU.

Comparison of available water chemistry data (Table B-11) indicated that of the parameters monitored, all remained within the MAC of the CDWSO (1978) except slightly elevated concentrations of iron and manganese.

- Wabana HU -

A total of 7 municipal wells have been drilled into this unit. Well depths range from 64-150 m. Estimated yields from borehole records range up to 90 Lpm; although a number have unknown yields. Discussions with Mr. M. Hammond indicated no major difficulties in obtaining domestic groundwater supplies within this unit.

Pump tests have been carried out on three municipal wells (Table D-1). Transmissivity values ranged from 6.0×10^{-6} - 1.6×10^{-4} m²/s with resultant recommended pumping rates of 18 - 75 Lpm.

Comparison of available water chemistry data (Table B-11) indicated that of the parameters monitored all remained within the MAC of the CDWSO (1978) except iron, manganese and sporadically turbidity.

In summary, groundwater yields capable of supporting domestic residences are relatively easy to obtain throughout the island. Relatively large yield municipal wells are apparently much more difficult except for perhaps within the Redmond HU.

The only documented use of surface waters is utilization of the reservoir on Freshwater Brook. However, it is only utilized for fire fighting.

D-2.1.2 Energy Resource

The definition of water as an energy resource in terms of hydroelectric power development from surface streams was beyond the scope of reference for this study.

TABLE D-1
Summary of Pump Test Analyses

Location	Well Data		Pumping Rate (Lpm)	Duration (hrs)	Pump Test Data		
	Total Depth (m)	Casing (m)			Saturated Thickness (m)	Static Level (m)	Transmissivity m^2/s
- Wabana HU -							
• Dr. Walter Templeman Hospital (Well No. 13)	91.5	30.0	61.5	44-88	72	A.G.S.	1.6×10^{-4}
• Housing Corp. Well (Well No. 4)	93			22.5-35	24	3.9	1.4×10^{-5}
• Front Pump House (Well No. 11)	152	12	140	48-126	48	9.5	6.0×10^{-6}
- Bell Island HU -							
• St. Edwards School (Well No. 10)	108	72	96	45-90	48	?	2.8×10^{-5}
• Lance Cove Well (Well No. 15)	96.3	6	90.3	41	24	7.9	1.3×10^{-5}

A.G.S. = Above Ground Surface

Another aspect of water as an energy resource is utilization of the energy stored in groundwaters to heat buildings through the use of groundwater heat pump technology. No groundwater temperatures have been collected on the island. Temperatures from a nearby automated shallow well monitoring site operated by Newfoundland Environment (Well No. 1, North Pond Brook, Torbay) indicated a range from 5-10°C. This is slightly above the mean annual air temperature of 6°C.

To our knowledge, there are no groundwater source heat pumps in use on the island. In the Sydney area of Nova Scotia where groundwater temperatures are in the same temperature range, a number of heat pumps are in use for heating domestic dwellings of 140 - 190 m² in size. These pumps extract approximately 4-5°C from the groundwater to produce 38°C air for distribution by producing some 40,000 Btu/h. The water demand required to operate the system is roughly 45 Lpm during operation.

Wells should be capable of yielding 65-70 lpm to ensure an adequate supply for both the heat pump and domestic usage without need for storage. Analysis of existing well logs and pump tests in the Bell Island and Wabana HU's suggest that even these moderate yields may be difficult to acquire from one well. In these HU's it would probably be necessary to go to a second well for recharge of the heat pump water. Theoretically, there should be no problems in acquiring these yields from the Redmond HU.

D-2.1.3 Attenuation of Contaminants

In contrast to the insignificance of the surficial HU's for water supply, they become critically important in terms of contaminant attenuation. This is principally dependent on the intergranular permeability and the percentage of fine grained sediment and organic matter. Very little data is presently available on the physical and biological attenuation mechanisms prevalent in any of the surficial or bedrock hydrostratigraphic units.

D-2.2 Present Utilization By Man

D-2.2.1 Water Supply

The available data indicates that the present water demand regardless of purpose is extracted from groundwater resources at some 450 - 600 DAM³ per year. This forms some 5-6% of the average annual

groundwater recharge rate. Approximately, 60-80% of this is returned back to the groundwater flow system via septic fields. The remaining 20-40% is directed by sanitary sewers directly into the ocean.

Some 80-90% of the demand is supplied by 19 municipal wells; 14 of which are located within Wabana. The remainder is provided by individual domestic wells.

At present, no fresh water is directly exported off-island. The only exception is a minor volume indirectly exported in vegetables grown via horticultural practices.

D-2.2.2 Contaminant Attenuation

At present, some eight major potential contaminant sources can be identified on the island, including:

- . 3 service stations
- . 2 bulk hydrocarbon tank farms
- . MSW disposal site
- . leaking sanitary sewers
- . tailings basin
- . coarse waste piles
- . road wash
- . areas of high septic field density

It must be stressed that this list is only intended to identify potential sources; there is no data available to determine if contamination exists, or if it does, the degree of impact on the existing resources. The only exception is within certain areas, primarily within the Town of Wabana, where poorly installed and/or too high a density of septic fields occur and have at times contaminated adjacent wells and nearby surface waters.

Of these potential sources only three incorporate a design which attempts to utilize the attenuation properties within the groundwater or surface water flow field. These are:

- 1) Septic field designs which attempt to utilize the soil and till HU's for attenuation.
- 2) Sanitary sewers providing direct partially treated discharge directly into the ocean for dilution, dispersion/buffering and
- 3) Surface streams on the island being utilized as receptor streams for handling untreated road wash runoff.

D-2.3 Water Resources Imbalances

A quantitative discussion of present and future imbalances within the existing system is impossible given the lack of pump test data on the municipal wells and daily demand.

Discussions with town officials suggest that in general the existing system of 14 municipal wells within Wabana appears to be capable of meeting the existing non-fire demands with regards to quantity. Although some wells have lower yields than others and some go dry, the combination of other higher yield wells and the interconnected distribution system seems to have allowed for sufficient flexibility to meet existing demands. How much additional demand can be placed on the system is unknown.

The main existing imbalance therefore appears to be the inability to provide suitable fire demands. The surface reservoir is in place but the associated tank and distribution line needs repair.

In terms of water quality, the absence of detailed water chemistry on each well, does not allow determination of whether the existing water quality allows the system to meet the potable and non-potable demands. If the major producing wells (Davidson Ave., Main St., Rock Cut) are or become non-potable in the near future due to contamination, a critical supply/demand imbalance may quickly become a reality.

The Gorman Butler report (1976) recommended alterations to the system to alleviate some of these problems. Specifically, this included a centralized water source to provide backup water supply and allow for proper retention for chlorination. This system encompassed construction of a 2.3×10^6 L storage tank at the St. Edward School, tied into the Davidson Ave., and Main St. wells, in conjunction with the surface water reservoir and chlorination facilities at each of the three sources. They felt this system would provide 2400 Lpm to meet the demand placed by 1000 people. Unincorporated areas were not to be serviced due to high cost. Additional work was also proposed to add modifications to the tank and distribution system to maximize pressure at critical points to expand fire protection services. However, as they indicated, the yields for the two wells are estimates only and technically unfounded. This system has not been implemented to date.

Discussions with Mr. Hammond, indicated that domestic wells within the unincorporated area usually acquire sufficient water for domestic needs. The Cumming's Hill area off Lance Cove however required greater well depths. There appears therefore to be no significant supply/demand imbalances, although again detailed water chemistries are still unknown. If a supply/demand imbalance should occur in the future recommendations are made in Section D-3.3.6 to attempt to develop a well field in the Redmond HU west of the surface water reservoir.

D-2.4 Water Resources Conflicts

Due to the lack of pump test data with observation wells it is presently impossible to state with any degree of accuracy whether there are any areas where competition for groundwater resources exist (i.e. pumping of one well which significantly influences another).

Although most of the wells are spread out over a wide area, the contribution of water from thin sandstone units striking northeast-southwest may create "line-sinks" in terms of drawdown cones which may extend some distance laterally. Also of note is that the three wells drilled into the Redmond HU (Davidson Ave., Rock Cut and Main St.) are relatively close together and may be affecting each other.

The main area of conflict noted at this time is confined to water quality issues and includes:

- 1) Within certain areas of Wabana the high density of septic fields use the groundwater flow field (principally in the Till HU) for attenuation in the same area as it is being utilized for water supply (i.e. No. 4 and Main Street wells).
- 2) Urban/suburban land use may also be reducing recharge rates and adding potential contaminants to the bedrock aquifer i.e. road wash, leaks from underground storage tanks, fertilizers on lawns, etc.

Due to the lack of detailed groundwater chemistry analyses it is impossible to identify areas with existing or emerging problems of deteriorating water quality.

D-3.0 WATER RESOURCES MANAGEMENT

D-3.1 Philosophy of Approach

The human cycle provides for an enormous variety of complex interactions at various scales between the SOCIO-ECONOMIC and ENVIRONMENTAL systems. The development of management "strategies", as defined in this report, necessitates an understanding of each system and their interrelationship i.e. so as to allow policy makers the ability to answer questions which weigh environmental risk against cost (either monetary or aesthetic) to society. In addition to those parameters investigated in this report, it implies a knowledge of the SOCIO-ECONOMIC system as well as the biological and saline water components of the ENVIRONMENTAL system which beyond this reports terms of reference. However, the Socio Economic system for the Island was briefly investigated and reported on in 1981 by the Provincial Planning office, Dept. of Municipal Affairs and Housing. Their recommendations were adopted by the Wabana Town Council in June 1981.

The data and conceptual models generated in this investigation has allowed for the development of planning for the rational development of specifically the fresh water resources of the environmental system. For the purpose of this report these plans will be referred to as management "schemes"; in opposition to "strategies".

The remainder of this section discusses:

- 1) the preliminary development of one management strategy upon which all other strategies can be built, and
- 2) a variety of management "schemes" to be utilized in managing the fresh water resources.

D-3.2 Management Strategy - Organization of a Management Authority

The Provincial and Federal Governments have certain powers in existing legislation to aid in the protection of the water resources on Bell Island. However, such powers fall within the overlapping jurisdiction of a large number of agencies.

The principal provincial agencies are: Environment and Lands, Public Health, Municipal Affairs, Fisheries, and Newfoundland Hydro. The principal Federal agencies are Environment Canada for Federal Crown Land (including Canadian Wildlife Service for all lands) and the Department of Fisheries and Oceans. Beyond these principal agencies there are numerous

other bodies which have indirect control over water resources i.e. by controlling land use i.e. Departments of Forestry, Mines and Energy and Municipal Councils.

Unfortunately, there is presently no one body or agency specifically responsible for not only developing long term management plans for the island; but just as importantly supervising day-to-day operations. This will require changing from the existing single purpose, single agency activity to a complex interdisciplinary, multi-purpose, multi-agency planning and management strategy.

Therefore, the following recommendation is put forth to serve as the key management "strategy" for the island:

An organization should be set up and charged with the responsibility for not only developing short, medium and long term management "strategies"; but also for supervising day to day activities on Bell Island. For the purposes of this report it will be tentatively referred to as the Bell Island Water Management Authority (BIWMA).

In researching the multitude of organizational structures that have been set up in other areas, it was felt that the Ohio River Basin Commission had a simple, flexible approach that may form a basis for developing the BIWMA.

The Commission's approach to planning and management was summed up (Joering, 1980) as:

"determining where you are, where you want to go and what should be done next to get from where you are to where you want to go"

"Where you are" - necessitates an inventory of resources and an assessment of how well they meet existing needs.

"Where you want to go" - compare goals and projections to existing conditions to define needs and future problems.

"What to be done next" - Commission designs and implements plans which are revised every four years.

What was also pertinent in terms of minimizing cost was the organization of the Commission.

The Commission does not manage the resource as a single-all-powerful entity. Commission members are derived from existing organizations that already have responsibility for some aspects of

management. In the Bell Island case this could for example include representatives of Newfoundland Environment, Federal Environment, Federal Fisheries, Newfoundland Department of Municipal Affairs, major proponents, local citizens communities, Wabana Town Council, etc..

The value in this approach to management is that the only added cost is possibly for a small professional staff and additional staff time required for each commission member. This is a rather small incremental cost compared to the cost of developing a whole new bureaucracy to manage all aspects, fiscal and otherwise of the system. In addition, it allows a more efficient management without threatening or expanding existing authorities.

The plans developed by the Commission are then the result of the combined interdisciplinary work of literally hundreds of people rather than a handful of technical staff employed by the Commission.

As such, the Commission accomplishes three things:

- 1) it co-ordinates all water and related land plans whether federal, provincial, municipal or private.
- 2) it prepares a plan of development for the use of the resources, and,
- 3) it recommends priorities for implementation, detailed studies, preliminary investigations and research/data collection.

In striving toward a number of these goals, a close relationship with Newfoundland's Interdepartmental Land Use Committee will be very beneficial.

D-3.3 Management Schemes - Fresh Water Resources

This section discusses a variety of management "schemes" to aid the BIWMA in the rational utilization of specifically the fresh water resources of the Island.

It must be stressed that the following list is by no means intended to be comprehensive either in number of schemes or in-depth description of each scheme. Instead they have been developed based upon the practical experience of Nolan, Davis & Associates in the region, as well as discussions with regulatory agencies and proponents. The ideas developed were than worked up to the extent possible given the budget available.

In the development of the following schemes and in any alterations made to them in the future, Howell's (1981) comments should be kept in mind:

"While planning is essential to water resources management there is no way to accurately predict needs in the distant future. There is too much uncertainty involved. Even the pursuit of alternative futures is limited by present perceptions of advances in technology, population growth and distribution, world food needs, status of the economy and myriad other factors. So, plans must be flexible and adaptable to unforeseen circumstances and decisions and their consequences must not be irreversible".

D-3.3.1 Development of Continuous Working Models

There are probably numerous ways that management of the water resources can be undertaken especially given the complexity of the situation. Such complexity is derived from:

- 1) the complex interactions of the hydrogeological, debris, geochemical and biological cycles which alter with space and time
- 2) the complexities of the human cycle and its impacts on the existing water resources
- 3) our lack of knowledge of the above cycles and inability to accurately predict impacts
- 4) the problems associated with bringing together a diverse group of individuals in an authority from different perspectives and levels of government.
- 5) the need to constantly revise models and strategies based upon the acquisition of new information

In order for the authority to operate effectively, it will be necessary to come up with some method of deriving order out of this apparent chaos.

Literature searches have revealed one means through which management could be accomplished. Although it is by no means the only way, it does have merit and is put forward at this time as a suggestion or starting point upon which to build.

The basic concept of the model was developed for groundwater management in the lignite mining areas of Germany. Given the hierarchy of decision making and constantly shifting interaction of activities with the environment, the methodology of Continuously Working Models (CWM's) was developed.

The basic concepts of this model were utilized to form a base upon which to build a model especially suited for the Bell Island situation. The results (Figure D-1) are discussed below. The model is comprised of essentially four components: 1) modelling, 2) level of detail required for investigations, 3) user of the information and 4) feedback loops; as discussed briefly below:

- A) On the left side of the diagram, is the interaction of the four cycles (hydrologic, debris, geochemical and biological) pertinent to assessing fresh water. These cycles are "modelled" either conceptually or numerically to form a regional view of the existing environment in the form of Drainage Basin Model A.
- B) The practical utilization of the information derived from the model creates a problem since the users of the data required it for a variety of reasons and response times, i.e. ranging from the need for real-time data to just annual summaries. It would appear that a three-level hierarchy may prove suitable for this situation. This is defined within the three boxes listed under Level Of Detail Required, and comprises:
 - 1) the local or detailed scale with a need for real time data to facilitate day-to-day operations of facilities i.e. static and pumping water levels associated with municipal wells.
 - 2) medium scale required for planning/design of new large facilities i.e. Environmental Impact Assessments.
 - 3) a regional model on an Island wide perspective i.e. planning of new well fields, development of protection and management strategies.
- C) These three levels of detail relate specifically to a similar hierarchy in the policy/decision making process carried out by the users of the data as shown on the far right side of the diagram.
- D) To provide for flexible up-to-date decision making there are two feedback loops. The first is from the "users" to allow decisions to be reflected quickly into operations and 2) to allow new data coming in to be added to the existing data base which would allow for a revising of the initial Drainage Basin Model A to form model B.

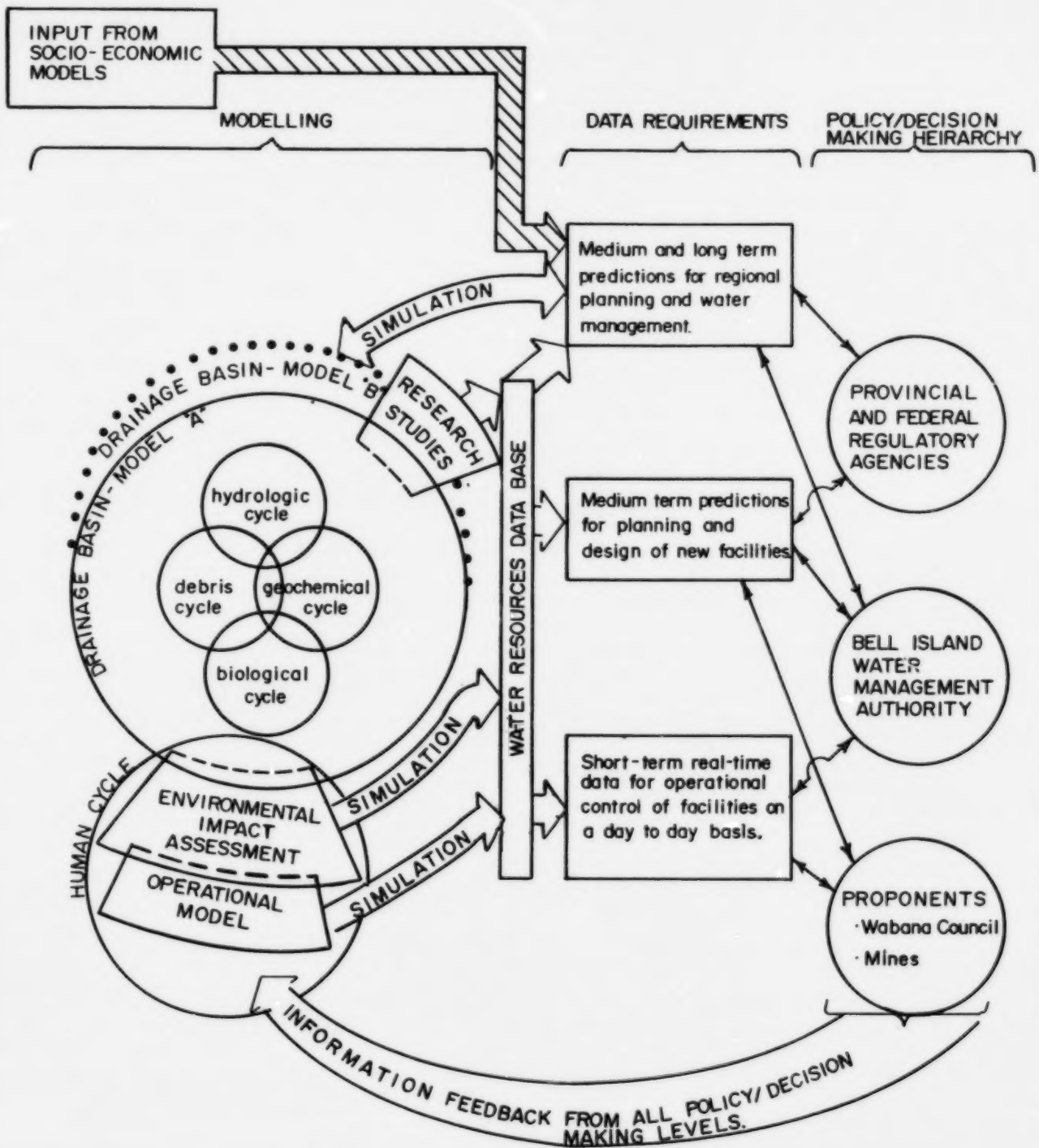


FIGURE D-1
SUGGESTED HEIRARCHY OF CONTINUOUS WORKING MODELS FOR BELL ISLAND

As an example of the system at work, this report has created drainage Basin Model A with the existing data. If in the future some portion of the Human Cycle is to be changed or altered it is then modelled and overlapped with Basin Model A (possibly via an Environmental Impact Assessment) to determine the location, type and extent of alterations to be created in the natural cycles as well as the resultant impacts and their significance. All raw data collected is placed in the water resources data base. The conclusions and recommendations are reviewed by the Provincial and Federal Regulatory Agencies as well as the BIWMA. Any necessary mitigation measures and operation stipulations to ensure protection of the resource are decided upon and passed back to the proponent, becoming part of the operational guidelines (operational model).

The data collected from monitoring programs during operations would be used by the proponent in his own day-to-day decision making and by the BIWMA to initially assess compliance with guidelines. This data would also go into a data base which could be utilized by the latter and Federal and Provincial Agencies to continue to update and revise the drainage basin models. This would allow continual refinement of protection and management strategies and operational stipulations.

Both the BIWMA and Provincial and Federal Regulatory Agencies can conduct research studies to better quantify the natural cycles in areas not covered by EIA's, so as to improve the drainage basin models. At this same level of policy making, the results from the Socio-Economic models may also be inputted.

A key ingredient in the process is the realization that models form an image of reality with a certain accuracy. The accuracy of the simulation results depend on the completeness and quality of the existing information. Therefore, it is imperative that all data be kept in a water resources data base. The acquisition of new data in practice, forms a feedback system which allows for a constant improvement to refine the accuracy of results as well as to improve the viability of the design of mitigation measures and management strategies.

In assessing the application of CWM's it must be emphasized that they are a helpful tool in medium-term planning and design as well as short-term control, but their applicability for long-term planning as an

integrated part of the regional policy making process will be restricted by the extent of development of the Socio Economic Model.

D-3.3.2 Monitoring/Research Programs

The solution of numerous problems of optimization of groundwater development is impossible without an understanding of its occurrence, quantity and quality and how this varies with time. As indicated in Section B of this report, a number of data gaps exist in our knowledge of the cycles. It is therefore considered of paramount importance to develop monitoring/research programs in order to acquire the relevant data.

In order to develop such programs, the information presented in Section B was assessed to determine if "sufficient" knowledge was available for understanding the factors governing the quantity and quality of the resource. However, the determination of what constituted "sufficient" was difficult. For the purposes of this report, the following assumptions were utilized:

- TEMPORAL - "sufficient" data constituted the ability to determine at least gross "seasonal" fluctuations and annual averages
- SPATIAL - "sufficient" data constituted the ability to at least break the island down into gross areal and vertical units

It should be noted that this section was designed as a first step to specifically identify major areas where monitoring is required; not to design each monitoring program. This method of approach is summarized by Gerard (1965):

" In science we commonly think that quantitative precession is our great strength; and, certainly, it does give science its essentially unique power of precise prediction and hence control. But before measurements can be meaningful, they must be directed to the right things and even in science, finding these things is the major achievement."

D-3.3.2.1 The Hydrologic Cycle

Pertinent conclusions/recommendations concerning data gaps in what are considered to be the most pertinent components of the hydrologic budget equation.

- BOUNDARIES -

- . In any budget study it is necessary to have defined boundaries. The hydrogeological lower boundary of the three bedrock HU's is unknown. The 91 m boundary limit used is believed to be conservative given the existing domestic wells.
- . It should be determined at what depth significantly reduced fracturing and/or saline water intrusion identifies the lower boundary of the fresh water lense on the Island.

- PRECIPITATION -

- . There appears to be a large variability in climate data from surrounding climate stations.
- . At least a temporary manual climate station should be established on the Island (in co-ordination with Environment Canada, Atmospheric Environment Service) to record daily rainfall, snowfall, total precipitation and air temperature.

- SUBSURFACE INFLOW -

- . Conceptual modelling indicates that critical components governing groundwater flow are infiltration into the bedrock and the three bedrock HU's.
- . Field determinations should be carried out to:
 - determine the volume of seasonal and annual recharge infiltrating into the bedrock aquifer.
 - investigate hydraulic conductivity, thickness, porosity, transmissivity, storage coefficient and anisotropy of the three bedrock HU's; but priority should be given to the Redmond HU, given its potentially high production capabilities. This can be carried out through exploratory diamond drilling and piezometer installation in combination with water well test drilling with associated pumping tests.

- STREAMFLOW -

- . Given the total absence of any pertinent data on the island at least a temporary, manual hydrometric station should be set up to gauge a natural drainage basin on the island.

- SUBSURFACE OUTFLOW -

- . The field data gathered in the above sections should be utilized to undertake 2-D or 3-D numerical modelling of the Bedrock HU's. This would be used to assess groundwater watershed divides, locate recharge and discharge areas, and estimate rate of flow movement.
- . Flow meters should be installed on all pumping wells in order to assess rate and volume of existing withdrawals.
- . A house-to-house survey should be completed on those homes on individual supplies, to determine the type and characteristics of water supply systems.

- CHANGE IN GROUNDWATER STORAGE -

- . Maintain the existing monitoring well in the Bell Island HU.
- . Install a similar recorder within the Redmond HU.

- ATTENUATION -

In developing a hydrologic budget, "volume" is the key component assessed. However, in assessing water quality the character of flow is important in determining the attenuation of contaminants. Dispersion, diffusion and dilution coefficients however are quite variable in time and space. Analysis, if carried out, should be confined to project specific areas associated with existing or proposed disposal sites.

Geochemical Cycle

Pertinent conclusions/recommendations concerning data gaps in what are considered to be the most pertinent components on a practical basis are outlined below.

- Precipitation

- . Given the location of the Island immediately downgradient of the Holyrood power plant, acid precipitation could be a major factor in assessing long term changes in water quality.

- It is recommended that a long term, automated, event based, sampler be set up on the island to monitor the chemistry of at least wet fallout. If possible, dry fallout chemistry should also be assessed.

- Bedrock hydrostratigraphic Units

- Very little data is available on the water chemistry/quality of groundwaters within the three principle HU's used for water supply on the Island.
- A groundwater sampling program should be undertaken on pertinent existing wells, springs, and new test wells to at least establish a range of concentrations for each separate HU re: major ions, nutrients, metals, physical parameters and organics (as characterized by TOC and Humic acids)

- Surface Waters

- Given the absence of surface water chemistry data a program should be set up to establish sufficient data to characterize the natural chemistry indicative of the island. This would aid in assessing the possible conjunctive use of both ground and surface waters to supply potable and non-potable demands.

- POINT AND NON-POINT CONTAMINANT SOURCES -

- The dominant man-made potential sources of contaminant inflows were identified in Section C.
- None of these sources are presently being monitored.
- It is recommended that hydrogeological investigations be undertaken on any such major point sources which are located over the sub/outcrop of the Redmond HU to identify the presence extent/type/direction and rate of travel of "contaminants". Specifically, this would entail at least the three service stations, major transportation corridors, as well as individual septic systems/sanitary sewers.

Attenuating processes, i.e. precipitation, co-precipitation, sorption, buffering etc. are quite variable in time and space. Therefore, projects should be confined to specific project areas.

A total of 10 major research programs have been identified for implementation. These by no means will cover all the data gaps but are considered to be those of a higher practical importance.

D-3.3.3 Permit System

Based upon the existing permit system the following suggestions are put forward:

- 1) Major existing water users (i.e. wells utilized for other than domestic purposes) not presently on a permit and future major users should be requested to apply for some form of water rights permit. Such a system would help alleviate future competition for the resource as well as aid in protecting the quality of the resource.
- 2) The industrial/municipal liquid waste discharge permits should be continued.

D-3.3.4 Setting Up A Data Base

To be effective, the development of any management schemes must be based on all the up-to-date factual data available. This implies a data gathering, storage and retrieval system especially given the large volume of diversified data which can be pertinent to the study of water resources. The models developed for this study are conceptual only; due to the lack of data. Such models must be updated as new data becomes available in order to be relevant in the designing of practical management schemes. At some stage enough data will be available so that numerical modelling can become a valid tool.

In our experience, a water resource data base must:

- 1) be independent of time (i.e. it must be continually updated)
- 2) allow for flexibility (so that the data may be interpreted on a wide variety of scales), and
- 3) allow for rapid dissemination of the data to any user.

The following recommendations are therefore considered relevant:

- 1) All pertinent information should be located spatially on a large scale map, with the data to be held in attribute files.
- 2) The scale of the mapping chosen in consultation with Newfoundland Environment was 1:12,500 so as to allow for interpretation at this large scale and at any variety of smaller scales. Map 1 is designed to be the data base map.

It is envisaged for the moment that mapping will take the format of this paper copy. However, in our experience, maps are easily misplaced, borrowed, torn and difficult to reproduce quickly for immediate utilization by the user. In the long term, NDAL would suggest that serious consideration be given to implementing some form of the Geographic Information Software (G.I.S.) system to computerize the map. The resultant mapping can be shown digitally on a screen or in hard copy. Specific data requested by the user can be withdrawn from the attribute files and shown on the screen as single data or overlapped with other information. The result is a data base which can be easily updated, reproduced, and non-destructable.

- 3) The attribute files are designed to contain all the raw data in such a way as to be cross referenced with the base map. In our experience such files should include (but not be limited to), the following core categories: well logs, climate data water and sediment chemistry, pump test analyses, stream discharge records, water rights applications waste management (septic fields, disposal site, storage of "dangerous" goods) and land use.

The data available to date under these Categories is included at various spots within this text. Again this data may be kept in paper files, with the same inherent problems encountered with the mapping. In the long term, it would be more advantageous to computerize these files, especially if computerized mapping is utilized. The Geobase System suggested is presently being modified to accept attribute files using the DBase 3 format.

From our experience, one of the main problems in developing the attribute files is how to link the data with the mapping in terms of where the data is spatially located on the map. Two methods are feasible, one is to identify the property on which the data is located through use of a PID (property identification) number. The second method is to identify a specific point on the map to which the data is applicable to and enter the co-ordinates in the computer. There are pro and cons to each method.

To aid in establishing co-ordinates for point source data, the base map utilizes the Universal Transverse Mercator Grid co-ordinate system. Initially, there was some difficulty with the easting co-ordinates on the base map obtained from Lands and Forests. Corrections were necessary to bring it in line with the UTM grid shown on the NTS mapping.

In order to commence the computerizing of attribute files, it was assumed that computer mapping was a future goal. In addition, the Lotus 1, 2, 3 format was already in use to some degree by Newfoundland Environment. Therefore, the Well Inventory file was computerized utilizing the Lotus format and presented to the client with this report. A printout is given in Appendix C.

D-3.3.5 Environmental Impact Assessment

In order to better assess the impact of future large scale projects, a proponent must undertake an Environmental Impact Assessment (EIA). Such approval comes under the discretionary powers of the Minister of Environment and Lands as defined under the Environmental Assessment Act. To date, there have been no such assessments carried out on the island.

It is recommended that in future EIA's Environmental Effects Monitoring Programs (Beanland and Duinker 1983) should be emphasized as part of the stipulations in order to better assess the impact of the project and gain valuable data for parts of the monitoring programs recommended in D-3.3.2.

D-3.3.6 Definition of Safe Yield

It is not sufficient to know just the renewable and non-renewable water resource. The data must be coupled with a knowledge of the safe yield before the percentage of the total volume available to man can be

determined. It is this latter figure upon which allocation of water to different users can be made.

To further complicate the issue, the value of "safe yield" can vary temporally and spatially depending upon such parameters as: scale of investigation, economics, users other than man, technology, water treatment, etc.

These problems necessitate the following recommendations:

- 1) An attempt should be made to define the "safe yield" of the system. It is suggested that this begin in three specific areas:
 - A) The present data indicates the potential importance of the Redmond HU as a major groundwater supply. The safe yield of this HU should be investigated primarily over the southwest end of the island. This is where natural land use prevails, and there is a low probability of contamination, therefore groundwater protection strategies can be more easily instituted and enforced. If successful, this could then serve as the major well field augmenting and/or replacing the existing supply for Wabana.
 - B) Of the municipal wells presently supplying the majority of residences on the island, only one has been pump tested to assess its safe yield. It is suggested that each of these wells be pump tested using a combination of step drawdown and constant rate pump test procedures. At the same time:
 - i) the pumps could be pulled from the wells to determine type, efficiency, depth setting and operational status,
 - ii) well depths and amount of case pipe could be quantified
 - and iii) if considered necessary a video tape of the casing and well could be made with a down-the-hole camera to assess lithology, fracturing, water bearing horizons, incrustation and surface water inflow around the edge of the casing, etc.

This data would allow for an assessment of the short and long term yields of the well, the efficiency/capability of the pumping system to extract the available water, and potential contaminant problems. The data should then be stored in the data base to form the basis for an operational record for each well. On a priority basis, the three wells extracting water from the Redmond HU should be tested first (i.e. Main Street, Davidson Ave. and Rock Cut wells).

- C) At the other end of the scale Safe yield calculations should be undertaken at a drainage basin Scale for the Freshwater Brook watershed. This basin was chosen due to its relatively large size, proximity to population centers, it's present utilization for storage regarding fire protection, and its location over the Redmond HU with subsequent important ground-surface water interactions.

In these calculations it is recommended that a number of scenarios be assessed, ranging from the simple inflow - outflow concept (where safe yield cannot exceed the "renewable" resource of the basin) to conjunctive ground - surface water management. In the latter case "mining" of the groundwater storage reservoir can occur for periods of time to replenish surface water during summer and drought demands.

- 2) In the determination of "safe yield" water quality plays an important role i.e. how much and/or at what rate can water be withdrawn before degradation of water quality occurs which makes it unfit for the "user".

There are four points of concern in this regard which we have identified to date:

- A) Salt water intrusion: The induction of salt water intrusion into the bedrock aquifers by over pumping is of concern. To

date no such occurrences have been identified. However, the extent of the fresh water lense on the island has also not been identified.

Part of the reason for the absence of salt water intrusion problems likely stems from the fact that the water bearing sandstone facies are protected from Saline waters by the overlying low permeability shale/siltstone facies. The only major pathway for intrusion would be laterally along strike originating at the point where the sandstone facies outcrop at or below sea level. At the present time there are no major producing wells close to the coast at these points.

During the pump tests on the municipal wells, water samples should be taken and the analyses assessed for any evidence of this occurrence. If the Redmond HU is developed as a major well field it may be necessary to install piezometers into the aquifer near the coast to act as an early warning of lateral salt water intrusion into the aquifer.

- B) Past urban/suburban industrial land use in the northeastern sector of the island quite likely has contaminated the bedrock aquifers to some extent. The development of any new wells in the area to the southwest should take into consideration the potential for either natural or induced flow to transport contaminants toward these wells, especially along the more highly permeable Redmond HU which has been targeted for drilling. If this HU is developed as a major well field, it may be necessary to install piezometers into the aquifer between the wells and the urban area to act as an early warning of lateral movement of contaminated water toward the wells.
- C) As evidenced in our construction of the well for the Dr. Walter Templeman Hospital the upper, possibly more heavily fractured portion of the bedrock aquifer in the urban areas may exhibit undesirable water quality at least in terms of iron, manganese and H_2S . At this site, it was necessary to

case/grout this section of the aquifer off. However, overpumping may induce this contaminated water into the aquifer through the existing network or improperly abandoned wells.

- D) The 14 municipal wells being presently utilized in Wabana are located in proximity to the users. This places the wells and quite probably the subcrop of the sandstone units supplying water to the wells under urban/suburban/industrial land use. There is therefore a strong probability that aquifers have been contaminated to some extent with bacterial, dissolved constituents as well as light and/or dense non-aqueous phase organic liquids (LNAPL's and DNAPL's).

To date, none of the wells have been analyzed for the entire suite of parameters set out in the Guidelines for Canadian Drinking Water Quality (1978), nor the wide range of organic contaminants which have not as yet been placed on the Canadian list but are on either the U.S. and/or World Health Organization list. It is, therefore, strongly recommended that at least one sample be collected from at least each municipal well and analyzed for all these constituents in order to accurately assess its potability. If a number prove non-potable, it may hasten the need for developing an alternate well field.

D-3.3.7 Creation of Water and Waste Management Districts

To date, no one particular portion of the water resources on the island have been designated for certain specific uses. As a result, water supplies and waste disposal sites have been developed at sites selected for principally socio-economic reasons.

The concept of classification of waters into water and waste districts has been applied to surface waters for more than two decades. However, its utilization for groundwaters can create serious management problems. There may be relatively little difficulty in upgrading surface water quality, given the short turn around time in stream recovery. However, the turn around time for the natural upgrading of groundwater

sources is simply too long and uncertain and man-made rehabilitation schemes too expensive for upgrading to be considered as a practical management scheme at this time. Therefore, it would seem logical that all groundwaters presently suitable for human consumption should be preserved if at all possible for that purpose. In this way, it will be possible to preserve options and insure that future water needs will be met. In light of these considerations it is recommended that:

- 1) The Redmond HU should be ranked as a water management district. However, the imposition of such a ranking and the protection it implies has serious implications for water managers since a number of potential contaminant sources are presently and have been located over the out/subcrop of this HU for some time. Specifically this includes: three service stations with associated underground storage tanks, spills, road salt, road wash, and a number of sanitary sewers with potential leakage. Protection schemes for this district are discussed in Section D-3.3.8.
- 2) The existing municipal solid waste disposal sites and sanitary sewer systems should be identified as one waste management district. Data should be collected on the waste streams entering the disposal area, how they are impacting the existing water resources, and design buffer zones around the site to ensure water wells will not intersect or induce contaminant plumes into a water supply.

The existing disposal area, sewage outfall and site of a proposed sewage treatment plant are located at the east end of an area reserved for the future exploration of the mineral reserves. Specifically they are located at the most probable point of entry to the under sea future works. Management of this district will therefore be imperative.

D-3.3.8 Groundwater Protection Zones

Within Europe groundwater protection schemes are well established and involve several "protection zones" which radiate outward from a producing well.

Groundwater protection has been addressed to varying degrees throughout the U.S. The strategies developed all have in common the basis of establishing classes of groundwater based upon the level of protection needed to address present or future intended use rather than a "numerical" quality standard. This approach is founded on the philosophy that it is not possible to monitor every well and regulate every possible contaminant. In addition, the use concept allows flexibility to react to changing drinking water standards and newly discovered types of contaminants. This system also allows integration into land use planning in other sectors.

In Canada, the concept of groundwater protection strategies has received very little attention to date. Cons (pers. comm) concluded that it was not appropriate at this time to attempt to develop an aquifer or groundwater classification system in Canada as insufficient data was available for such an monumental task. However, there should perhaps be some focus on highly sensitive areas. In that regard, a three class system utilizing the U.S. concept has been designed for Nova Scotia. Three classes of indigenous groundwater quality can be recognized:

Class 1 - High quality groundwater - meeting objective concentrations of major physical and chemical parameters in the Guidelines for Canadian Drinking Water Quality 1978.

The total dissolved solids concentration shall be less than 500 ppm, and some naturally occurring elements could be above objective concentrations but below or reaching maximum acceptable concentrations in the Guidelines.

Hydraulic conductivity of the aquifer is greater than 4.7×10^{-7} to 4.7×10^{-6} m/s.

The Department of the Environment may designate an aquifer as Class 1 where it serves as the sole water supply for humans, regardless of hydraulic conductivity.

This class is designated in order to protect those aquifers used, or capable of being used for drinking water supply.

Class 2 - Intermediate quality groundwater - meeting objective concentrations of some physical and chemical parameters in the Guidelines.

The total dissolved solids concentration has values between 500 and 2,500 ppm, and many naturally occurring elements reach and some exceed maximum acceptable concentration in the Guidelines.

Hydraulic conductivity of the aquifer is lower than 4.7×10^{-7} to 4.7×10^{-8} m/s.

The Department of the Environment may designate an aquifer as Class 2 in order to protect those aquifers of poorer natural quality than Class 1 which are used, or may reasonably be expected to be used, as a source of drinking water, after treatment, or could be used for industrial and agricultural purposes.

Class 3 - Low quality groundwater - meeting objective concentrations of some physical and chemical parameters in the Guidelines.

The total dissolved solids concentration has values over 2,500 ppm, and many natural occurring elements and pollutants reach and some exceed maximum acceptable concentrations in the Guidelines.

The Department of the Environment may designate this aquifer for waste storage and treatment.

In summary, there appears then to be a wide variety of schemes to choose from. To date nothing has been set up as a Canada wide system or specifically for Newfoundland.

We are, therefore, suggesting consideration be given to utilizing two philosophies of approach on Bell Island, namely:

- 1) an aquifer classification scheme based on present and future use (utilizing the Nova Scotia example)
- and 2) a protection strategy based upon zones radiating outward from existing producing wells.

The quantification of both schemes is significantly hindered by the lack of pertinent hydrogeological data. Therefore, at this time, only generalized statements can be made. The collection of data from the programs recommended in Sections D-3.3.2 and D-3.3.6 would greatly facilitate development of both protection strategies.

Given these constraints, the following recommendations are put forth for consideration:

- 1) The Redmond HU should be classified as a Class 1 aquifer. An aquifer protection zone should be developed for that part of the aquifer west of the downstream end of the reservoir on Freshwater Brook. The reasons for this are three fold:

- A) The northeastern portion of the aquifer is probably, contaminated to some extent and will be very difficult to protect; whereas the western zone is under natural land use and protection schemes can be effectively developed.
- B) According to existing surficial mapping it is this western portion of the aquifer which has no till cover to aid in natural protection.
- C) The western section is the zone which has been budgeted for well drilling/testing program to ascertain the feasibility of developing a large well field for supplying future growth on the island.

Until further hydrogeological data is gathered, a conservative approach to protection is suggested. This would encompass no alteration land use patterns over the aquifer in this area.

- 2) The surface water watershed for the Freshwater Brook reservoir should be protected to ensure existing quantity/quality of water. This zone in large measure would be encompassed within the aquifer protection zone for the Redmond HU defined above.
- 3) Given the conceptual flow model governing salt water intrusion into the bedrock HU's it is suggested that an aquifer protection zone be set up primarily along the northeast and southwest end of the island, along the island's perimeter. Unfortunately the width of this zone, in which no wells should be drilled, has to be defined by hydrogeological properties of the more highly permeable sandstone units, for which no data is available. Therefore, an arbitrary limit of 300 m should be assigned until the recommended studies are carried out. This limit was based upon closest distance of most present domestic wells to the coast where no saline waters have been encountered.
- 4) A well head protection program should be designed and implemented around each of the major municipal wells on the island. This will be difficult, but more imperative, for those wells located within the urbanized areas, especially wells such as No. 4; due to the high density of septic fields around it, and Davidson Ave and Main St. wells due to the proximity of service stations.

Prior to development and implementation of these schemes, it is first necessary to determine if the well is already contaminated. To that extent, the recommendations in Section D-3.3.6 regarding detailed analysis of water from all municipal wells is critical.

These protection schemes utilize the concept of integrative time/distance variables. It is therefore necessary to quantify variables such as aquifer thickness, pumping volume, natural and induced groundwater velocity, effective porosity, and residence time of groundwater. Such data will only become available after recommendations discussed in previous sections are carried out.

It should be realized that if the wells are presently contaminated, it may be more efficient and critical to develop a new well field in an area which can be protected.

- 5) Given the dependence on individual wells in the past and the significant decline in population, it is suspected that there are a large number of improperly abandoned wells on the island. An abandoned well program should therefore be carried out to locate and properly seal off abandoned wells at least in two principal areas.
 - A) within the Redmond HU
 - B) within well protection zones
- 6) The Bell Island HU should be classified as Class 2 aquifer solely because of the low transmissivity. It is however recognized that it still yields sufficient volumes for domestic withdrawals and as such it is still imperative that it be protected.
- 7) It is suggested that the Wabana HU be classified as a Class 3 aquifer. This encompasses all bedrock units downdip (younger) of and including the Dominion Formation Lower Ore Member. Such a classification would allow it to be designated for waste storage, if necessary. This concept is based upon:
 - The surficial till cover has been removed, the ore bodies stripped out and no reclamation.
 - The area is already covered with abandoned, above grade, spoil piles from the stripping; thereby forming a potential contaminant source but also a source for fill material.

- . Very few sandstone beds are found within this HU and permeabilities are presumably quite low.
- . The existing municipal solid waste disposal site is located within this zone.
- . The proximity of this area to the coast suggests a higher probability of encountering salt water.
- . Any leachate moving out of the disposal area would probably flow down stratigraphic dip or along strike and in a short flow path enter a saline - high energy environment for attenuation. To our knowledge this zone is not used for man-made recreational purposes. The impact on the fisheries is not known.
- . Any new major industries coming to the island would appear to have some link with the abandoned mine workings. Therefore, any new facilities will probably be constructed near or in this zone. The associated waste stream could be therefore disposed of in an adjacent area, thereby negating large trucking costs.
- . The Redmond HU is protected from contaminants created by shallow subsurface burial of wastes in this zone by some 500 metres of relatively low permeable Bell Island HU.
- . This location on the northwest coast of the island places it at the downstream end of the groundwater flow system if it is governed solely by surface relief and bedding dips.
- . No municipal wells are presently located within this zone, although there may be individual domestic wells.

It should be pointed out, however, that if a disposal site is located in this zone, it will be necessary to ensure that leachate does not enter the underground workings.

D-3.3.9 Water Pricing

The traditional approach to water management through "supply" management serves well as long as water resources are abundant. This implies that as water use increases measures are taken to increase supplies (i.e. new dams, wells, etc.).

However, there are now clear signals across Canada that water resources management should also focus on "demand" management. This implies controlling demand by using water more efficiently.

Among the briefs received by the Canadian inquiry on Federal Water Policy the majority favoured water pricing as the approach to demand management. Economic principals indicate that when a resource is undervalued it tends to be overused.

In Wabana, the water rate per household is \$72.00 per year. Assuming four people to a house and 380 litres/person/day gives a cost per tonne of water of \$.13.

This is significantly undervalued in comparison to other commodities such as:

wheat, oats, corn	\$90 - \$118/tonne
hogs, cattle	\$990 - \$1400/tonne
haddock, cod, scallops	\$770 - 13,200/tonne
copper, platinum, aluminum, gold	\$1200 - \$14,000,000/tonne

It should also be noted that the above costs are just for the basic commodity and doesn't include the extra costs for processing and delivery.

However, the cost for water is delivered to the door. The cost is comprised totally for extraction and distribution. There is no intrinsic value given to water. It is imperative, therefore, to put flow meters on the wells to determine the volume of water utilized. If it is excessive, then some combination of demand management (increasing the price for water) and supply management (locating a new well field) in the Redmond HU may form the most efficient way of managing the island's water resources.

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APPENDIX A

Historical Stream Flow
Rocky River at Colinet

ROCKY RIVER NEAR COLINET - STATION NO. 022K001

ANNUAL EXTREMES OF DISCHARGE AND ANNUAL TOTAL DISCHARGE FOR THE PERIOD OF RECORD

YEAR	MAXIMUM INSTANTANEOUS DISCHARGE (m ³ /s)	MAXIMUM DAILY DISCHARGE (m ³ /s)	MINIMUM DAILY DISCHARGE (m ³ /s)	TOTAL DISCHARGE (mm)	YEAR
1948	112	AT 04:30 NST ON MAR 11	---	---	1948
1949	---	---	0.288	ON AUG 27	1949
1950	85.6	AT 15:00 NST ON OCT 5	0.204	ON AUG 22 *	1950
1951	160	AT 18:00 NST ON JAN 26	0.891	ON JUN 24	1951
1952	160	AT 21:30 NST ON FEB 6	0.895	ON JUL 30	1952
1953	283	AT 07:30 NST ON DEC 27	0.823	ON SEP 14	1953
1954	226	AT 04:00 NST ON DEC 8	1.38	ON SEP 7	1954
1955	126	AT 18:00 NST ON FEB 13	1.61	ON JUL 12	1955
1956	204	AT 13:30 NST ON NOV 10	1.80	ON FEB 12	1956
1957	186	AT 17:30 NST ON SEP 6	0.488	ON AUG 1	1957
1958	138	AT 11:00 NST ON MAY 31	2.07	ON AUG 18	1958
1959	185	AT 02:30 NST ON NOV 11	0.661	ON AUG 1	1959
1960	79.8	AT 17:00 NST ON APR 6	0.303	ON AUG 31	1960
1961	---	---	0.244	ON SEP 24	1961
1962	248	AT 08:00 NST ON FEB 11 *	1.08	ON SEP 12	1962
1963	102	AT 08:00 NST ON NOV 15	0.779	ON JUL 30	1963
1964	216	AT 08:00 NST ON DEC 19	1.63	ON JUL 26	1964
1965	108	AT 17:30 NST ON MAR 2	0.838	ON AUG 19	1965
1966	142	AT 20:00 NST ON DEC 15	2.22	ON AUG 18	1966
1967	101	AT 08:00 NST ON JAN 6	0.778	ON JUL 31	1967
1968	151	AT 18:30 NST ON AUG 27	1.89	ON JUL 16	1968
1969	183	AT 01:00 NST ON OCT 30	1.18	ON JUL 13	1969
1970	222	AT 16:55 NST ON FEB 27	1.18	ON AUG 2	1970
1971	284	AT 20:30 NST ON FEB 1	1.78	ON AUG 4	1971
1972	150	AT 21:58 NST ON NOV 27	0.778	ON AUG 4	1972
1973	143	AT 10:16 NST ON OCT 24	2.92	ON JUL 28	1973
1974	237	AT 01:03 NST ON AUG 31	1.88	ON AUG 14	1974
1975	120	AT 00:48 NST ON AUG 24	0.937	ON JUL 17	1975
1976	180	AT 04:58 NST ON JAN 9	0.886	ON AUG 31	1976
1977	86.0	AT 12:48 NST ON DEC 28	0.821	ON AUG 17	1977
1978	126	AT 01:30 NST ON DEC 19	0.840	ON AUG 17	1978
1979	86.1	AT 11:30 NST ON OCT 16	1.20	ON JUL 12	1979
1980	120	AT 17:36 NST ON AUG 18	2.89	ON FEB 16	1980
1981	160	AT 18:45 NST ON FEB 8	1.74	ON MAY 31	1981
1982	78.3	AT 01:32 NST ON NOV 25	1.22	ON AUG 18	1982
1983	182	AT 12:31 NST ON NOV 18	2.28	ON JUL 2	1983
1984	175	AT 22:28 NST ON FEB 7	0.982	ON AUG 11	1984
1985	122	AT 11:25 NST ON MAY 28	1.80	ON AUG 21	1985
1986	138	AT 18:23 NST ON MAR 28	1.36	ON AUG 24	1986
A - MANUAL GAUGE (SEE REFERENCE INDEX)					MEAN
B - ICE CONDITIONS					356 000
C - ESTIMATED					
* - EXTREME RECORDED FOR THE PERIOD OF RECORD					
R - EXTREME SINCE JAN 1 1988					

NEWFOUNDLAND AND LABRADOR

ROCKY RIVER NEAR COLINET - STATION NO. 02K001

MONTHLY AND ANNUAL MEAN DISCHARGES IN CUBIC METRES PER SECOND FOR THE PERIOD OF RECORD

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN	YEAR
1948	---	---	---	---	---	---	---	---	---	---	---	---	---	1948
1949	---	---	---	---	5.11	3.81	6.810	0.548	3.16	15.7	3.95	---	---	1949
1950	17.0	7.80	11.1	25.8	11.2	2.76	1.08	0.613	1.84	11.8	8.16	8.34	8.08	1950
1951	21.6	13.5	15.4	17.7	10.0	2.20	2.07	6.89	7.30	6.39	17.7	18.2	11.8	1951
1952	28.7	23.6	10.8	11.5	5.41	3.83	1.89	3.45	14.3	6.07	21.8	10.1	11.8	1952
1953	15.1	15.3	12.0	18.0	6.02	4.78	3.12	1.82	1.72	16.3	15.8	31.1	11.8	1953
1954	18.2	18.7	17.3	10.6	10.2	5.88	4.93	7.48	4.93	11.2	9.12	21.1	11.8	1954
1955	24.2	15.5	12.8	11.7	12.6	12.5	4.86	7.23	4.98	15.9	23.8	13.7	11.8	1955
1956	17.2	8.53	13.8	18.8	14.2	10.9	8.38	8.71	14.0	8.82	26.8	18.6	13.5	1956
1957	27.2	12.2	17.8	11.6	6.85	2.04	2.02	2.19	14.1	8.88	14.6	22.6	11.8	1957
1958	15.2	8.07	9.19	8.87	6.28	9.85	7.03	7.45	7.89	8.92	16.4	11.4	8.80	1958
1959	8.54	14.1	8.00	22.2	11.4	5.18	1.24	4.26	4.98	4.81	26.5	10.7	8.80	1959
1960	6.86	12.0	8.28	18.4	8.19	2.87	1.09	1.80	1.38	8.11	12.2	14.8	7.89	1960
1961	8.84	3.78	14.8	15.8	10.7	2.88	0.888	0.880	0.828	8.11	14.3	11.3	8.82	1961
1962	10.9	36.9	14.8	11.4	3.51	5.85	8.81	4.38	5.38	8.88	21.2	13.8	7.02	1962
1963	21.8	8.67	3.20	17.8	12.2	6.44	1.84	8.71	8.86	4.83	11.0	13.8	11.8	1963
1964	12.9	13.8	6.83	36.8	8.85	4.28	6.20	8.11	8.36	20.4	11.0	18.8	9.08	1964
1965	10.7	11.8	16.0	14.2	7.32	5.48	9.09	1.27	1.17	4.88	14.3	11.3	12.4	1965
1966	10.2	7.88	12.2	14.8	12.8	6.78	11.1	4.80	5.08	9.39	6.81	28.7	8.82	1966
1967	12.8	17.8	11.3	13.0	16.8	3.51	1.88	1.88	7.33	7.16	16.7	8.32	11.0	1967
1968	12.0	7.48	17.8	7.84	18.8	14.2	8.25	10.1	6.34	7.88	13.7	18.8	8.88	1968
1969	8.49	21.8	18.0	13.7	8.24	6.82	4.18	14.8	17.3	17.7	12.1	18.8	10.7	1969
1970	5.86	33.1	17.4	8.88	9.82	7.77	3.18	20.6	7.02	37.2	17.8	17.1	18.4	1970
1971	12.2	20.6	12.7	23.4	8.41	7.84	7.82	4.80	5.08	7.33	20.4	13.3	12.7	1971
1972	14.8	12.7	11.3	11.8	18.8	5.88	1.78	2.85	6.27	20.1	20.8	12.1	11.8	1972
1973	11.0	24.8	7.81	8.28	13.4	14.8	6.23	15.0	7.32	11.4	16.4	10.9	12.1	1973
1974	8.88	4.78	7.48	18.8	13.1	7.83	5.70	8.32	14.8	27.0	14.2	18.8	12.1	1974
1975	7.88	7.88	8.70	28.1	11.8	3.88	2.28	10.1	8.34	14.9	17.3	13.0	10.3	1975
1976	28.4	22.4	11.7	14.8	8.88	8.82	3.80	2.88	8.23	15.7	10.8	18.6	12.2	1976
1977	28.4	8.81	12.1	10.0	7.08	2.82	2.00	3.22	8.87	7.47	8.38	18.6	12.2	1977
1978	28.4	10.4	18.8	22.0	18.8	10.8	3.81	1.83	13.8	8.87	10.3	12.1	8.28	1978
1979	11.4	7.22	28.8	19.7	7.78	4.18	6.00	8.95	9.22	18.9	12.8	12.0	10.9	1979
1980	20.6	18.3	10.0	9.88	9.82	14.4	11.7	13.1	13.3	18.4	16.9	18.8	14.9	1980
1981	8.44	8.42	12.2	18.8	9.71	8.48	9.12	9.48	10.1	21.8	18.2	12.7	12.9	1981
1982	24.8	22.8	20.4	11.0	6.88	10.8	8.88	7.74	10.8	8.72	8.08	24.0	10.8	1982
1983	17.2	22.8	8.36	24.7	18.8	6.83	3.32	6.21	11.8	4.32	8.11	10.8	12.0	1983
1984	6.18	8.03	7.28	13.8	25.7	6.34	12.2	3.71	5.48	4.34	10.8	9.37	11.3	1984
1985	20.8	11.8	28.8	20.3	5.88	11.8	3.70	3.71	6.18	8.80	18.1	7.83	8.80	1985
MEAN	18.1	13.6	13.2	18.7	10.2	8.80	4.83	6.34	7.84	11.8 R	14.7 R	18.0 R	11.3	MEAN

LOCATION - LAT 47 13 28 N LONG 53 34 08 W DRAINAGE AREA, 285 KM² NATURAL FLOW

R - REVISED SINCE JAN 1985

APPENDIX B

Precipitation Chemistry
CAPMON Station at Bay D'Espoir

CANADIAN AIR AND PRECIPITATION MONITORING NETWORK (CAPMnN)

SUMMARY STATISTICS

STATION NAME: BAY DESPOIR
PERIOD: 01JAN84 TO 31DEC84GAUGE
DEPTH
(mm)SUPL.
DEPTH
(mm)COLL.
EFF
(%)

z

CONCENTRATION IN MILLIGRAMS PER LITRE

pH

H+

SO₄²⁻XSO₄²⁻NO₃(N)Cl⁻NH₄(N)Na⁺Ca⁺⁺Mg⁺⁺K⁺

Acid

Alk

TOTAL PREC DAYS
#TRACE PREC DAYS
#NON-TRACE PREC DAYS
VALID SAMPLES
% VALID SAMPLES
%TOTAL PREC-VALID
% COLL EFF-VALIDARITHMETIC MEAN
ARITHMETIC S.D.
GEOMETRIC MEAN
GEOMETRIC S.D.
WTD STATISTIC
- NORMAL
- LOG-NORMALMINIMUM
25TH PERCENTILE
50TH PERCENTILE (MED)
75TH PERCENTILE
MAXIMUMPW MEAN-STND (MG/L)
PW MEAN-MAX (MG/L)
TOTAL DEPTH-STND (CM)
TOTAL DEPTH-MAX (CM)
DEPN-STND (KG/HA)
DEPN-MAX (KG/HA)

SEA SALT CORR

NOTE:

* - DATA NOT CONSISTENT WITH STATED DISTRIBUTION AT 95% SIGNIFICANCE LEVEL

- NOT APPLICABLE OR NOT DETERMINED

+ - PW MEAN pH (IN pH UNITS) CALCULATED FROM PW MEAN CONCENTRATION OF H⁺

T - TRACE

N/C - PW MEAN CONCENTRATION AND DEPN NOT CALCULATED WHEN TOTAL PRECIP-VALUE < 70%

CANADIAN AIR AND PRECIPITATION MONITORING NETWORK (CAPM+N)

SUMMARY STATISTICS

STATION NAME:
PERIOD:BAY D'ESPOIR
01JAN85 TO 31DEC85GAUGE DEPTH
(mm)SUPL DEPTH
(mm)COLL EFF
(%)

pH

H+

SO₄²⁻XSO₄²⁻NO₃(N)Cl⁻NH₄(N)

Na+

Ca++

Mg++

K+

Acid

Alk

CONCENTRATION IN MILLIGRAMS PER LITRE

TOTAL PREC DAYS

#NON-TRACE PREC DAYS

VALID SAMPLES

% TOTAL PREC-VALID

% COLL EFF-VALID

ARITHMETIC MEAN

GEOMETRIC S.D.

GEOMETRIC MEAN

GEOMETRIC S.D.

WIND STATISTIC

- NORMAL

- LOG-NORMAL

MINIMUM

25TH PERCENTILE

50TH PERCENTILE (MED)

75TH PERCENTILE

MAXIMUM

PW MEAN-STND

(MG/L)

PW MEAN-MAX

(MG/L)

TOTAL DEPTH-STND

(CM)

TOTAL DEPTH-MAX

(CM)

DEPN - STND

(KG/HA)

DEPN-MAX (KG/HA)

SEA SALT CORR

13%

NOTE:

* - DATA NOT CONSISTENT WITH STATED DISTRIBUTION AT 95% SIGNIFICANCE LEVEL

: - NOT APPLICABLE OR NOT DETERMINED

** - PW MEAN pH (IN pH UNITS) CALCULATED FROM PW MEAN CONCENTRATION OF H+

T - TRACE

N/C - PW MEAN CONCENTRATION AND DEPN NOT CALCULATED WHEN TOTAL PRECIP-VALUE < 70%

SUMMARY STATISTICS

CONCENTRATION IN MILLIGRAMS PER LITRE

[illegible]

* - DATA NOT CONSISTENT WITH STATED DISTRIBUTION AT 95% SIGNIFICANCE LEVEL
 + - NOT APPLICABLE OR NOT DETERMINED
 - PW MEAN pH (IN pH UNITS) CALCULATED FROM PW MEAN CONCENTRATION OF H+
 T - TRACE
 NC - PW MEAN CONCENTRATION AND DEPN NOT CALCULATED WHEN TOTAL RECIPIENT VALUE < 70%

APPENDIX C

Well Inventory File

WELL NO.	OWNER	ADDRESS	WELL COMPLETION DATE	DRILLER	LOG	TOTAL DEPTH (m)	WELL DIAM.	WATER ZONES	WELL LOCATION	PUMP TEST DURATION
	Dept. of Mun. Affairs	Confed. Bldg. St. John's	Oct. 19/84	Martin Hammond	None	120.0	150	110 m	Bell Island East End	Yes (1 hr)
6	Town of Wabana	Wabana	1965	?	None	103.3			353620E 5277150N 1W/N10E	No
8	Town of Wabana	Wabana	?	?	None	64.3	152mm Csg. 203mm Open Hole		353980E 5276940N	No
11	Town of Wabana	Wabana	?	?	None	64.0	152mm Csg. 203mm Open Hole		354025E 5277730N	No
10	Town of Wabana	Wabana	1965	?	None	190.5	152mm Csg. 203mm Open Hole		354530S 527815W	No
13	Town of Wabana	Wabana	?	?	None	?	152mm Csg. 203mm Open Hole		353820E 527640N	No
1	Town of Wabana	Wabana	Sept 26/79	Martin Hammond	0-117.4m: Grey Shale/Limestone	117.4	152.4mm		351282E 5276590N	Yes (1 hr)
3	Town of Wabana	PO Box 1229 Wabana, Bell Island	?	?	None	152.0	152mm Csg. 203mm Open Hole		352497E 5277800N	No
2	Town of Wabana	PO Box 1229 Wabana, Bell Island	Sept 29/79	Martin Hammond	0-202m: Grey Shale/Limestone	202.0	152mm Csg.		121.9 354925S 182.9 5277800N	Yes (1 hr)
7	Town of Wabana	PO Box 1229 Wabana, Bell Island	1966	?	None	161.5	152mm Csg. 203mm Open Hole	?	353820E 5276900N	No
9	Town of Wabana	PO Box 1229 Wabana, Bell Island	1966	?	None	121.9	152mm Csg. 203mm Open Hole	?	354470E 5276900N	No

WATER ZONES	WELL LOCATION	PUMP TEST DURATION	TEST PUMPING RATE	RECOMM. PUMP SETTING	RECOMM. PUMPING RATE	WATER QUALITY	SAMPLED DATE	CASING DEPTH	STATIC WATER LEVEL	WATER USE	FINAL WELL STATUS
110 m	Bell Island East End	Yes (1 hr)	54 L/min	105.0	50 L/min	Fresh				Public Supply	Abandoned Insufficient Supply
	353620E 5277150N 1N/110E	No		87.6		Clear, Hard Fe, Mn	1970		11.3	Municipal	Water Supply
	353980E 5276940N	No		30.5		Clear, Med. Hardness Mn	1976		25.3	Municipal	Water Supply
	354025E 5277730N	No				Colored Med. Hard. Fe, Mn	1976			Municipal	Water Supply
	354530S 527815W	No				Clear, Med. Hardness Fe, Mn	1976			Municipal	Water Supply
	353820E 527640W	No	?			Clear, Hard Fe, Mn	1976			Municipal	Water Supply
	351282E 5276590N	Yes (1 hr)	9 L/min	?	?	Clear		9.2	14.6	Municipal	Water Supply
	352497E 5277800N	No								Municipal	Water Supply
121.9 182.9	354925S 5277800N	Yes (1 hr)	34 L/min	?	?	Clear		6.7	12.2	Municipal	?
?	353820E 5276900N	No				Clear, Med. Hardness pH = 8.42	1976	?		Municipal	Water Supply
?	354470E 5276900N	No				Clear, Soft	1976	?		Municipal	Water Supply

WELL NO.	OWNER	ADDRESS	WELL COMPLETION DATE	DRILLER	LOG	TOTAL DEPTH (m)	WELL DIAM. (mm)	WATER ZONES	WELL LOCATION	PUMP TEST DURATION
5	Town of Wabana	PO Box 1229 Wabana, Bell Island	?	?	None	112.8	152mm Csg. 203mm Open Hole	?	353120E 5277820N	No
	Capitol Homes Ltd.	4 Jervis Place	Nov. 26/85	Martin Hammond	0-2m Br. Clay 2-6m Bl. Shale 6-94m Bl. Shale	94.0	150mm	30-90m		Yes (1 hr)
	Capitol Homes Ltd.	4 Jervis Place	Nov. 28/85	Martin Hammond	0-2m Br. Clay 6-30m Bl. Rock ?	30.0	150mm	24-30m	Brown's Lane Bell Island	Yes (1 hr)
	Capitol Homes Ltd.	4 Jervis Place	Nov. 21/85	Martin Hammond	0-2m Br. Clay 2-67m Bl. Shale	67.0	150mm	55-67m		Yes (1 hr)
	Capitol Homes Ltd.	4 Jervis Place	Nov. 22/85	Martin Hammond	0-2m Br. Clay 6-30m Bl. Shale 30-55m Gr. Shale	55.0	150mm	35-55m		Yes (1 hr)
	Capitol Homes Ltd.	4 Jervis Place	Nov. 25/85	Martin Hammond	0-3m Br. Clay 3-6m Bl. Shale 6-20m Gr. Rock 20-36.6m Bl. Sh.	36.6	150mm	?		Yes (1 hr)
	Capitol Homes Ltd.	4 Jervis Place	Nov. 25/85	Martin Hammond	0-2 Br. Clay 2-20m Gr. Rock 20-42m Bl. Shale 42-55m Gr. Rock	55.0	150mm	?		Yes (1 hr)
	Capitol Homes Ltd.	Jervis Place	Nov. 26/85	Martin Hammond	0-2m Br. Clay 2-70m Gr. Rock	70.0	150mm	42m 52m 68m		Yes (1hr)
	Capitol Homes Ltd.	4 Jervis Place	Nov. 20/85	Martin Hammond	0-2m Br. Clay 2-55m Bl. Shale	55.0	150mm	32-55m		Yes (1 hr)

WATER ZONES	WELL LOCATION	PUMP TEST DURATION	TEST PUMPING RATE	RECOMM. PUMP SETTING	RECOMM. PUMPING RATE	WATER QUALITY	SAMPLED DATE	CASING DEPTH	STATIC WATER LEVEL	WATER USE	FINAL WELL STATUS
?		Yes (1 hr)	14 L/min	33.0	12 L/min	Clear	No	6	4.0	Domestic	?
27-36m		Yes (1 hr)	18 L/min	33.0	16 L/min	Clear	No	6	?	Domestic	Water Supply
20-36m		Yes (1 hr)	54 L/min	51.0	51 L/min	Clear	No	6	?	Domestic	Water Supply
15m 20m		Yes (1 hr)	4.5 L/min	22.0	4 L/min	Clear	?	6	3.0	Domestic	Water Supply
35-60m		Yes (1 hr)	9 L/min	57.0	7 L/min	Clear	No	6	13.0	Domestic	Water Supply
45.5m		No	?	?	?	Clear		12	?	Domestic	Water Supply
22m	?	Yes (1 hr)	22.5 L/min	23	?	Clear, Hard	No	6.15	3	Domestic	Water Supply
140m	?	Yes (1 hr)	9 L/min				No				Abandoned: Insufficient Quantity
125m	?						No				Abandoned: Insufficient Supply
30m	?	Yes (1 hr)	7 L/min	25	?	Clear	No	6	2	Domestic	Water Supply
?	353160E 5277880N	No	?	?	?	Clear, Hard Mn	1976			Municipal	

WATER ZONES	WELL LOCATION	PUMP TEST DURATION	TEST PUMPING RATE	RECOMM. PUMP SETTING	RECOMM. PUMPING RATE	WATER QUALITY	SAMPLED DATE	CASING DEPTH	STATIC WATER LEVEL	WATER USE	FINAL WELL STATUS
?	353120E 5277820N	No				?	?			Municipal	?
30-90m		Yes (1 hr)	2.2 L/min	91.0	2.2 L/min	Clear	No	6	15.2	Domestic	Water Supply
24-30m	Brown's Lane Bell Island	Yes (1 hr)	24 L/min	27.0	22 L/min	Clear	No	6	2.0	Domestic	Water Supply
55-67m		Yes (1 hr)	13.5 L/min	?	13 L/min	Clear	No	6		Domestic	Water Supply
35-55m		Yes (1 hr)	18 L/min	52.0	?	Clear	No	6	9.5	Domestic	Water Supply
?		Yes (1 hr)	13.5 L/min	37.0	13 L/min	Clear	No	6		Domestic	Water Supply
?		Yes (1 hr)	9 L/min	52.0	8 L/min	Clear	No	6	10.0	Domestic	Water Supply
42m 52m 68m		Yes (1 hr)	27 L/min	62.0	25 L/min	Clear	No	6		Domestic	Water Supply
32-55m		Yes (1 hr)	6.75 L/min	52.0	6 L/min	Clear	No	6		Domestic	Water Supply

WELL NO.	OWNER	ADDRESS	WELL COMPLETION DATE	DRILLER	LOG	TOTAL DEPTH (m)	WELL DIAM.	WATER ZONES	WELL LOCATION	PUMP TEST DURATION
Allison Clements	Bell Island	Nov. 03/85	Martin Hammond	0-1m Yel. Clay 1-6m Gr. Shale? 6-24m Gr. Rock 24-36.5 Bl. Shale?	36.5	150mm	?	Yes (1 hr)		
TJ Construction Ltd.	Upper Island Cove	June 21/85	Martin Hammond	0-2m Br. Clay 2-36.4m Gr. Rock	36.4	150mm	27-36.m	Yes (1 hr)		
TJ Construction Ltd.	Upper Island Cove	June 20/85	Martin Hammond	0-2m Br. Clay 2-36.4m Gr. Rock	36.4	150mm	20-36m	Yes (1 hr)		
Frank Skanes	Bell Island	June 30/87	Martin Hammond	0-5m Br. Gravel 5-24m Gr. Rock	24.0	150mm	15m 20m	Yes (1 hr)		
George Cobb	Parsonville	Nov. 18/85	Martin Hammond	0-1m Yel. Clay 1-6m Br. Shale 6-60m Br/Gr Shale	60.0	150mm	35-60m	Yes (1 hr)		
Ken Kavanah	PO Box 996 Bell Island	Jan. 3/86	Brian Serle (?)	0-12m Br. Sand & Gravel 12-48.5m Bl. Shale	48.5	150mm	45.5m	No		
Ralph Skanes	Bell Island	Sept. 19/83	Martin Hammond	0-2m Yel. Clay 2-6.2m Wh. Rock 6.6-30m Wh.-Red- Gr. Rock	30	150mm	22m	Yes (1 hr)	?	
Roman Catholic School Board	St. John's	June 29/84	Martin Hammond	0-2m Gr. Fill 2-180m Gr. Rock	180	150mm	140m	Yes (1 hr)	?	
Roman Catholic School Board	St. John's	June 29/84	Martin Hammond	0-4m Yel. Clay 4-150m Red Rock	150	150mm	125m		?	
Gerald Kitchen	Lance Cove Bell Island	June 24/84	Martin Hammond	0-2m Yel. Clay 2-6m Gr. Rock	40	150mm	30m	Yes (1 hr)	?	
Town of Mabana	PO Box 1229 Mabana, Bell Is.	?	?	None	48.8	152mm Csg- 203mm Open Hole	?	No	353160E 5277880N	

WELL NO.	OWNER	ADDRESS	WELL COMPLETION DATE	DRILLER	LOG	TOTAL DEPTH (m)	WELL DIAM. (mm)	WATER ZONES	WELL LOCATION	PUMP TEST DURATION
2	Town of Mabana	PO Box 1229 Mabana, Bell Is.	1950	?	None	24.4	152mm Csg. 203mm Open Hole	?	354135E 5277890N	No
	Doris L. Bennett	Main St., Frount, Bell Island	Oct. 1961		None	27.4	152mm	?	354135E 5278660N	No
	Jim Sahty	Lance Cove Road	June 6/85	Pat O'Brian (Dynamic Drilling Ltd.)	0-0.6m Red Top. 0.6-1.8m Gr. O/B 1.8-50.3m Black Slate	50.3	203mm Csg. 150mm Open Hole	42.7m		No
	Bob Stone	Bell Island	Sept. 9/86	Chris Hammond	0-1.5m Red Top. 1.5-30.5m Gr. Bed	30.5	150mm	24-30m		Yes (1 hr)
	Raymond Lahey	Lance Cove Road	Dec. 22/86	Pat O'Brian	0-0.61m Red Top. 0.61-44.22m Br. & Bl. Shale	44.22	150mm	38.1m		?
	Wernick Ryan	Bell Island	Aug. 28/86	Chris Hammond	0-3.1m ? 3.1-45.7 Black Bedrock	45.72	150mm	?		Yes (1 hr)
	Local Service District	Lance Cove Road	April 23/87	Pat O'Brian	0-1m Red Topsoil 1-2.1m Br. O/B 2.1-93.0m Grey Shale & Sandstone	93	152mm	25.2- 80.8m		Yes (1 hr)
	Town of Mabana	PO Box 1229, Mabana, Bell Is.	July 23/85	Martin Hammond	0-2m Br. Shale 2-11m Gr. Shale 11-13.4m Gr Shale	13.4	150mm	15-50m	354850E 5276750N	Yes (1 hr)
	Greg Donier	Lance Cove Road	Sept. 12/87	Martin Hammond	0-1.2m Br. Clay 1.2-30.5m Bl. Bed 30.5-48.8m Bl/Br. Bedrock 48.8-79.3m Gr/Bl. Bedrock 79.3-85.3m Wh/Gr/ Bl. Bedrock	85.3	150mm	30.4- 85.3m		Yes (1 hr)

WATER ZONES	WELL LOCATION	PUMP TEST DURATION	TEST PUMPING RATE	RECOMM. PUMP SETTING	RECOMM. PUMPING RATE	WATER QUALITY	SAMPLED DATE	CASING DEPTH	STATIC WATER LEVEL	WATER USE	FINAL WELL STATUS
?	354135E 527780N	No	?	?	?	Clear, Med. Hardness, Mn, Low pH	1976	?	?	Municipal	Water Supply
?	354135E 527860N	No	?	?	?	Clear, Hard Fe	Yes	?		Domestic	Water Supply
42.7m		No	23 L/min	?	?	Clear	?	6.7		Domestic	Water Supply
24-30m		Yes (1 hr)	18 L/min	27	16 L/min	Clear	No	?		Domestic	Water Supply
38.1m		?	27 L/min			Clear	No			Domestic	Water Supply
?		Yes (1 hr)	4 L/min	42	3.5 L/min	Clear	No			Domestic	Water Supply
25.2-80.8m		Yes (1 hr)	115 L/min							Public Supply	Water Supply
15-50m	354050E 527675N	Yes (1 hr)	9 L/min		9 L/min	Clear	?		11	Public Supply	Water Supply
30.4-85.3m		Yes (1 hr)	13.5 L/min	82	12 L/min	Clear				Domestic	Water Supply

WELL NO.	OWNER	ADDRESS	WELL COMPLETION DATE	DRILLER	LOG	TOTAL DEPTH (m)	WELL DIAM.	WATER ZONES	WELL LOCATION	PUMP TEST DURATION
	Paul Brown	Lance Cove Road	Sept. 10/87	Sam Lone	0-1.5m Br. Clay 1.5-24.4m Bl. Rock 24.4-48.8m Bl/Gr. Bedrock	48.8		30.5- 48.8m		Yes (1 hr)

WATER ZONES	WELL LOCATION	PUMP TEST DURATION	TEST PUMPING RATE	RECOMM. PUMP SETTING	RECOMM. PUMPING RATE	WATER QUALITY	SAMPLED DATE	CASING DEPTH	STATIC WATER LEVEL	WATER USE	FINAL WELL STATUS
30.5- 48.8m		Yes (1 hr)	13.5 L/min	45	12 L/min	Clear					Domestic Water Supply

APPENDIX D

Municipal Wells Fact Sheet

PUMPING STATION INVENTORY

WATER DEMAND

PUMPING STA	LOCATION	WELL NO.	RES APPRO	COMMA	INST.	DEMAND (AVE. PEAK) L/M (IGPM)	AT WELL m	AT HIGH PT m	DEPTH m	PUMP LEVEL m	DIAM mm	CASING LENGTH m	WELL YIELD L/M (IGPM)	TYPE (HF)	PUMPING CAPACITY (@40 psi) L/M (IGPM)
A: INCORPORATED AREA (WABANA)															
Middleton Ave. 1979	N.W. Corner of Town	1	30	-	-	24-48 (5-11)	82	88	117	76	150	6	90 (20)	Subm. (1.5)	53 (12)
No. 4	No. 2 Road 400m N. of Vocas.	2	210	2	1	168-335 (37-75)	84	93	122	103	150	12	unknown	Subm. (15)	396 (88)
No. 3	No. 2 Rd. West of Vocas.	3	60	1	-	48-96 (11-21)	72	75	64 113	50 88	150 150	12 12	unknown unknown	Subm. (5) Subm. (10)	270 (60) 320 (70)
Namore	East Nail Area	4	35	-	-	28-59 (7-13)	40	45	122	112	156	12	68 (15)	Subm. (5)	120 (27)
Quigley's	Quigley's Lane	5	85	2	-	71-141 (16-32)	62	70	152	76	150	12	68 (15)	Subm. (5)	180 (40)
Fanny Hill	Martin's Rd.	6	60	1	-	48-96 (11-21)	90	92	100	91	150	12	45 (10)	Subm. (3)	90 (20)
Main Street	Martin's Rd.	7	140	-	-	117-254 (25-51)	68	68	190	160	150	12	unknown	Subm. (15)	260 (57)
Road Out	Railroad St.	8	180	9	11	158-301 (33-67)	84	84	84	64	150	12	unknown	Subm. (7.5)	320 (71)
Woods Ave.	Kennings's Lane	9	90	-	-	75-149 (16-32)	101	104	162	66	150	9	unknown	Subm. (7.5)	144 (32)
St. Edwards	Woods Ave Near	10	40	2	3	36-72 (8-16)	102	106	73	66	150	12	81 (18)	Subm. (2)	81 (18)
Front Well	Old Lance Bld.	11	50	-	-	43-85 (9-19)	86	90	152	88	150	12	45 (10)	Subm. (5)	153 (34)
Devilson Ave	Devilson Ave	12	120	1	3	100-200 (23-45)	87	90	103	66	150	12	unknown	Subm. (7.5)	180 (40)
Hospital	No. 2 Road	13	-	-	1	33-47 (8-16)	62	62	92	85	150	12	90 (20)	Subm. (2.0)	63 (14)
Voc. School	No. 2 Road	14	-	-	1	33-47 (8-16)	86	86	108	100	150	12	unknown	Subm. (5.0)	135 (30)
B: UNINCORPORATED AREAS (LANCE COVE, FRESHWATER, BICKFORDVILLE)															
Lance Cove	Lance Cove	15	22	-	1	19-37 (4-8)	80	80	93	85	150	6	81 (18)	Subm. (1.5)	236 (52)
Broder's Hill	Lance Cove	16	20	-	-	19-37 (4-8)	135	135	59	47	150	6	unknown	Subm. (1.5)	428 (95)
Well "A"	Lance Cove	17	16	-	-	19-37 (4-8)	100	100	69	63	150	6	68 (15)	Subm. (1.5)	320 (71)
Bickfordville		18	21	-	1	24-48 (5-11)	82	107	67	61	150	3	81 (18)	Subm. (3.0)	134 (30)
Logans Park	Bickfordville	19	-	-	-	-	105	105	60	50	150	-	60 (14)	-	-

PUMPING STA	LOCATION	WELL NO.	PUMPING ACCESSORIES	PUMPING ACCESSORIES	STORAGE	ADDITIONAL COMMENTS
A: INCORPORATED AREA (WABANA)						
Middleton Ave 1979	N.W. Corner of Town	1	-	-	-	-
No. 4	No. 2 Road 400m No. of Vocat.	2	6 Pressure Tanks 3050	6 Pressure Tanks 3050	-	-
No. 3	No. 2 Rd. West of	3	-	-	-	5 H.P. used sparingly
Normore	East Nail Area	4	Booster Pump	Booster Pump	-	Landfill 150m to south
Quigley's	Quigley's Lane	5	Booster Pump + 4 Pressure Tanks	Booster Pump + 4 Pressure Tanks	12000 gals. (atmos.)	Surface & storage tanks not oper. at present
Fancy Hill	Martin's Road	6	Compressor + 2 Pressure Tanks	Compressor + 2 Pressure Tanks	-	-
Main Street	Martin's Road	7	5 Pressure Tanks	5 Pressure Tanks	-	Reported to have high yield
Road Out	Railroad St.	8	-	-	72000 lt. (abn.)	-
Woods Ave.	Kennough's Lane	9	5 Pressure Tanks	5 Pressure Tanks	-	Well has run dry
St. Edwards	Woods Ave. near	10	1 Pressure Tank	1 Pressure Tank	-	Near Pump Tank
Front Well	Old Lance Road	11	4 Pressure Tanks	4 Pressure Tanks	-	Algae on Pump
Davidson Ave.	Davidson Ave.	12	5 Pressure Tanks	5 Pressure Tanks	-	Reported to have high yield
Hospital	No. 2 Road	13	-	-	22500 lt.	-
Voc. School	No. 2 Road	14	-	-	-	-
B: UNINCORPORATED AREAS (LANCE COVE, FRESHWATER, BICKFORDVILLE)						
Lance Cove	Lance Cove	15	-	-	-	-
Brother's Lane	Lance Cove	16	3 Pressure Tanks	3 Pressure Tanks	-	-
Well "A"	Lance Cove	17	-	-	-	-
Bickfordville	Bickfordville	18	-	-	-	Not presently in use
Logwood Park	Bickfordville	19	-	-	-	-

**MAPS
NOT
FILMED**

**CARTES
OMISES**